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OVERVIEW OF THE CHALK POINT COOLING TOWER PROJECT 1972 – 1979

MARCH 1979

Prepared by

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

for the

MARYLAND POWER PLANT SITING PROGRAM

DEPARTMENT OF NATURAL RESOURCES ■ DEPARTMENT OF HEALTH AND MENTAL HYGIENE ■ DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOPMENT ■ DEPARTMENT OF STATE PLANNING ■ COMPTROLLER OF THE TREASURY ■ PUBLIC SERVICE COMMISSION ■ DEPARTMENT OF TRANSPORTATION

JHU

PPSP-CPCTP-27

OVERVIEW OF THE CHALK POINT COOLING TOWER PROJECT 1972 – 1979

MARCH 1979

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ABSTRACT

The objectives, methodologies, data, and analytical results of the Chalk Point Cooling Tower Program are reviewed. The overview integrates the concepts and activities of the various program elements to provide a coherent view of the program in its entirety. Samples of the various data acquired are included together with very brief summaries of the conclusions. The report is extensively referenced to provide specific directions to the more extensive treatments of the program, data tabulations, and tape libraries available in the complete library of Chalk Point reports. The Chalk Point data is a resource for the study of cooling tower salt deposition processes and impacts in general. The methods used, while developed to facilitate the assessment of salt drift impact at Chalk Point, also have applicability to cooling tower impact analysis at other sites.

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NOTICE

This report was prepared for the State of Maryland as an account of work jointly sponsored by the State of Maryland, the Electric Power Research Institute, Inc. (EPRI), the U. S. Department of Energy (DOE), The Environmental Protection Agency (EPA), and the Potomac Electric Power Company (PEPCO). Neither EPRI, DOE, PEPCO, members of EPRI, DOE, EPA or PEPCO, nor any person acting on behalf of either:

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The University of Maryland

The Environmental Systems Corporation

Meteorological Research Incorporated

The Applied Physics Laboratory/The Johns Hopkins University

Art work, tabular material, and portions of the text have been reproduced from the original sources.

It is recognized that the selection of material for inclusion here is in itself a form of editing. The text is liberally referenced, however, and it is urged that serious workers in the field consult the appropriate references as needed.

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CHAPTER I

INTRODUCTION

This summary report provides a brief description of the concepts, design, data, and results of the Chalk Point Cooling Tower Project (CPCTP) during the period 1972-1979. The CPCTP is an experimental program designed to study the emissions and establish the effects of these emissions (salt and water vapor) on the crops, soils and native vegetation surrounding the natural draft cooling tower at Chalk Point. Also included is the study of aircraft and ground level icing and fog. It is intended that the summary report, while presenting a coherent view of the program in its entirety will also serve as a guidebook to those who may desire further information on the project. The various chapters therefore are extensively referenced to project literature.

The Chalk Point Electric Generating Facility is located on the Patuxent River at the extreme southerly point of Prince George's County, Maryland. The facility consists of four units. Units No. 1 and No. 2 are coal-fired, straight-through cooled units of 350 MWe capacity each. Units No. 3 and No. 4 are each designed to deliver 600 MWe. They are oil-fired cycling units and each utilizes a 700 foot stack for emission of combustion gases and a 400 foot natural draft cooling tower as a part of its closed circuit cooling system. The cooling towers, Figure 1-1, are cross flow towers and constructed as parts of Units No. 3 and No. 4 of the plant. At the time of the experimental program only Unit No. 3 was operational. The pertinent characteristcs of the cooling tower are given in Tables 1-1 and 1-2. Make up water for the cooling tower and for the particulate scrubber in the stack is brackish. The experimental program was primarily designed to investigate the environmental impact of salt drift emissions from the cooling towers upon crops, native vegetation and soils surrounding the facility.

BASIS OF THE PROGRAM

On January 11, 1971, PEPCO submitted to the Maryland Public Service Commission an application for a Certificate of Public Convenience and Necessity for the construction of Chalk Point Unit No. 3 with a closed cycle cooling system employing a natural draft cooling tower as described above. In June 1971, the Public Service Commission approved construction with the condition that a research and monitoring program be conducted to determine the specific conditions and operating constraints (if any) which should be imposed on the operation of the system. In response to this requirement, the Chalk Point Cooling Tower Project was conceived in 1972 by the State of Maryland, Power Plant Siting Program as a method of determining the environmental impact of drift emissions from the tower on soils and plants. The program was jointly

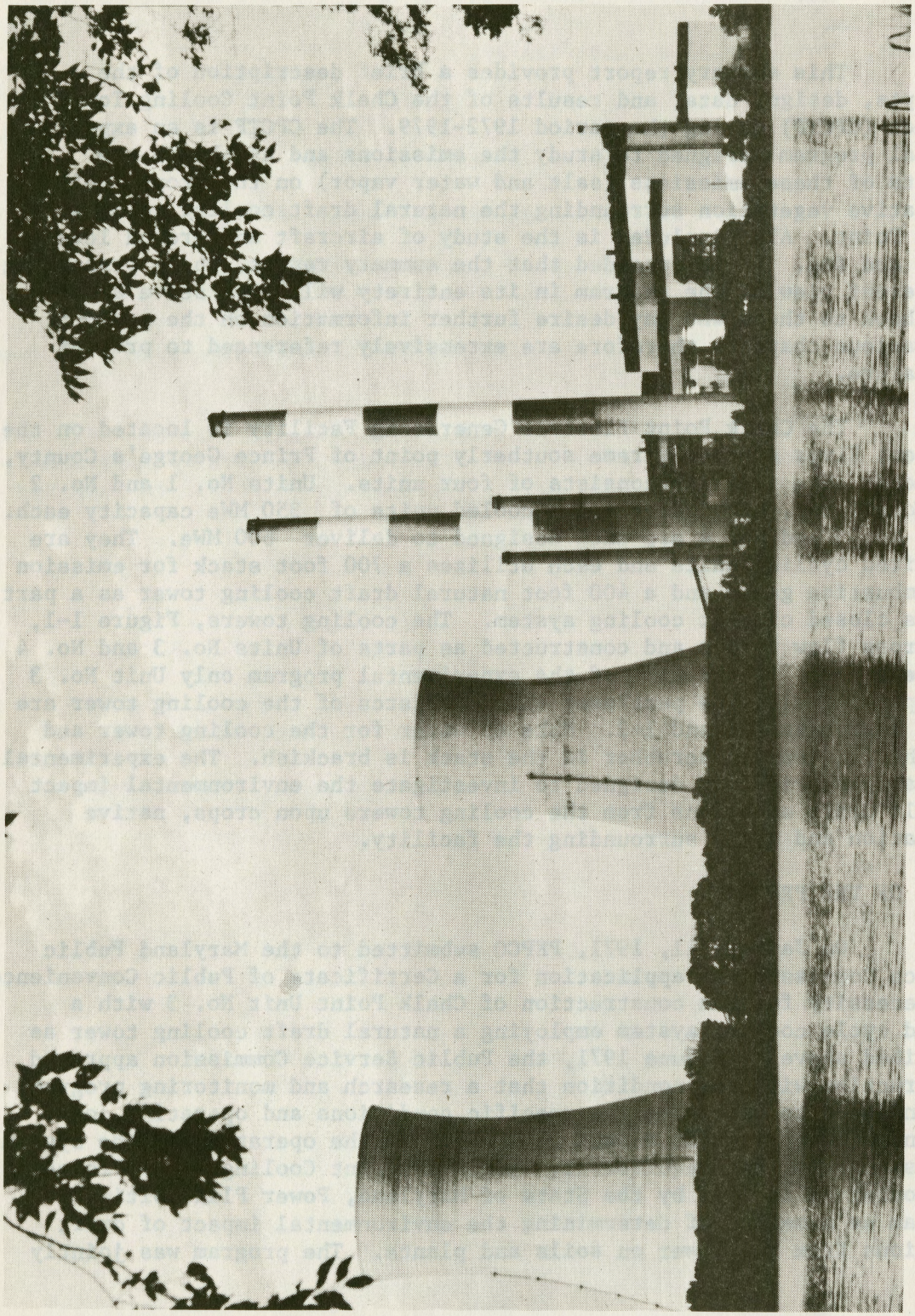


Fig. 1-1 Chalk Point electric generating plant.

Simulated Drift Studies. Plots of corn, soybeans, tobacco and native vegetation (trees) were treated with various levels of salt aerosol sprays in an attempt to establish salt tolerance levels of these plants. In addition, the salt buildup in soils was monitored throughout these tests. The tests were continued over a number of years and the results as reported by the University of Maryland are summarized in Chapter IV.

Field Monitoring Studies. A second part of the University of Maryland program involved the long term (several years) monitoring of agricultural crops and native perennials at test sites on and near the Chalk Point site. In addition to the test plots, native stands of trees were selected for monitoring. The tests were initiated prior to the operation of Unit No. 3 and are continuing. Conclusions to date appear in Chapter IV.

Drift Emission and Transport Studies

A major emphasis of the CPCTP has been on the cooling tower emission characterization and the predictive modeling of drift transport and deposition. Special instrumentation has been utilized for characterization of the in-tower plume and drift characteristics, the external plume characteristics, the drift deposition characteristics, and the upper air meteorology.

Internal Tower Measurements were acquired under contract with the Environmental Systems Corporation (ESC) using special instrumentation designed and built by ESC. The instrumentation package was suspended at or above the throat of the tower. Internal tower temperatures, relative humidity, and updraft velocity were monitored using this package. In addition the package contained an isokinetic sampler (IK) which was used to measure the total salt emission. Furthermore, drift size/number distribution data were obtained by a special "Particulate Instrumentation by Laser Light Scattering" device (PILLS) and by a sensitive paper probe. Both of these devices are mounted in the instrumentation package. ESC provided these internal tower measurements for all phases of the program. The ESC instrumentation package is described in Reference 1-2.

Salt Deposition and Airborne Salt Concentration data were taken by ESC using salt sensitive filter papers and their Airborne Particle Sampler (APS). Such data were taken at a number of fixed sites at Chalk Point and in the later stages of the program at portable monitors located under the plume and relatively close to the cooling tower. This instrumentation is described in Reference 1-2.

Airborne Measurement were acquired under contract with Meteorological Research Incorporated (MRI) using an airplane instrument for the

acquisition of plume meteoroloigcal data. The basic sensors were supported by a comprehensive digital data recording system. This airplane and its instrumentation were used in the two Intensive Test periods described in this report and are described in Reference 1-3.

Radiosonde Data were acquired under contract with the Applied Physics Laboratory/The Johns Hopkins University (APL/JHU) during the intensive tests and other special tests. These data provide lapse rates and upper air wind velocity information. Details of this data acquisition work are given in Reference 1-4.

The Basic Test Programs

The CPCTP test program consisted of three phases. They are the Initial Characterization, Continuous Monitoring, and Seasonal Intensive Tests. Sample data from each of these phases is presented in Chapter III.

Initial Characterization. These experiments were designed to permit the characterization of the internal tower plume in terms of updraft velocity, temperature, and dewpoint, the selection of a representative plane for subsequent measurements (i.e., a plane near the exit with acceptably low vertical velocity variation with position) and the measurement of typical drop size vs number distribution and total salt flux in that plane. In addition, the purpose of these experiments was to select a representative point for continuous monitoring of the plume over extended periods. The tests are described in Chapter III.

Continuous Monitoring. The purpose of these experiments was to provide continuous cooling tower emission data concerning the stability of drift characteristics over time.

Seasonal Intensive Tests. These test programs were conducted to provide full data sets for modeling over extreme meteorological conditions. Source term, ground deposition and concentration, airborne monitoring and meteorological data and plume photography were recorded. The winter seasonal tests were conducted December 15-19, 1975 while the summer seasonal tests occurred in June 17-24, 1976. These tests are summarized in Chapter III.

The Dyed Drift Test

To assist in the evaluation of the transport and deposition of cooling tower emissions APL/JHU suggested that a dyed drift test be considered. It was proposed that a dye tracer be added to the cooling tower water so that downwind deposition from the tower could be unambiguously separated from drift from stack No. 3 and/or background sea salt. At the

request of the State of Maryland this test was conducted by APL, in cooperation with ESC and PEPCO, on June 16 and 17, 1977. The conduct of the test included, in addition to the ground deposition measurements of dyed drift by APL, source term and salt deposition measurements taken by ESC as in the Intensive Tests, and radiosonde data collected by APL. A complete data set was obtained for use in model tuning. This test is summarized in Chapter III.

Analysis

Data from the tests described above have been utilized in a number of analytical studies designed to estimate the environmental impact of the salt and vapor emissions from the Chalk Point Cooling Towers. These results are summarized in Chapter IV.

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1-2 Schofner M., Schrecker G., Carlson T., Webb R., and Wilbur K., Cooling Tower Environment 1974, Proceeding of a Symposium, NTIS, CONF-740302, 1975.

1-3 Woffinden, George, et al, Cooling Tower Plume Survey, PPSP-CPCTP-15, Volume 1, MRI, November 1976.

1-4 Chalk Point Surface Weather and Ambient Atmospheric Profile Data, Second Intensive Test Period, PPSP-CPCTP-11, APL/JHU, January 1977.

CHAPTER II

OBJECTIVES OF THE CHALK POINT COOLING TOWER PROJECT

The major objectives of the Chalk Point Cooling Tower Program are:

1. Establish the environmental impact of salt water drift emissions from the Chalk Point Cooling Tower by continuously monitoring native soils, annual vegetation (especially agronomic crops) and perennial vegetation (woody species) within the deposition area of the tower.

2. Develop research methodology and establish (a), the symptoms of injury to crops and vegetative species due to the deposition from the Chalk Point cooling tower and (b) the threshold level of salt deposition which causes injury to agronomic and native species.

3. Produce a practical validated salt drift transport and deposition model suitable for use in accurately predicting salt drift transport and ground level deposition of salt emission from the Chalk Point natural draft cooling towers.

4. Produce a practical and validated vapor plume model suitable for use in predicting visible plume length and potential for ground fogging and ground level icing.

5. Develop an archival data base suitable for the development and validation of vapor plume and drift transport models.

6. Determine the range of variation of cooling tower emission parameters (especially drift) and ground level salt measurements over the meteorological and load conditions experienced over a year's operation. Also investigate the sensitivity of these parameters to deviations from the cooling tower design values.

Historically, objective 1 was the original objective of the project. The University of Maryland initiated a program to monitor the crops, soils, and measure the and salt deposition in the vicinity of the Chalk Point power plant before and after the operation of Units 3 and 4. The results of this effort gave the correlation of effects on crops, vegetation, and soils with salt deposition and climatology. This would probably be adequate for a <u>local</u> assessment of the impact of the cooling tower on the area around Chalk Point, but it would not have provided the capability to predict such impacts at other sites. Consequently, the objectives were expanded.

To satisfy objective 3 an extensive experimental program was implemented to acquire this data. The data acquired during this program should be sufficiently complete to allow the exercise of other models by other investigators. Included within this experimental program are the measurements of drift drop size distribution and integrated drift liquid water content in the plume.

Objective 4 is closely related to Objective 3 and as a consequence much of the experimental work required to satisfy one will satisfy the other. However, there are critical data collected by instrumentation peculiar to each of the two cases. Because of this, equipment failure could be expected to affect these two objectives differently. It is for this reason that the separate identity of these objectives was retained.

Objective 5 is intended to provide data to other investigators in the field, the data acquisition was not to be restricted to a specific modeling concept. Rather a standardized archival data package was to be developed and made available.

The achievement of objective 6 requires the addressing of operability over an adequate and pre-established domain of meteorological and load conditions.

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CHAPTER III

DESCRIPTION OF EXPERIMENTS AND EXAMPLES OF DATA

The experimental work conducted in The Chalk Point Cooling Tower Project is described in this chapter. These experiments consisted of the following studies:

1. University of Maryland (U of M) Vegetation and Soil Studies
2. Initial Characterization
3. Continuous Monitoring
4. Seasonal Intensive Tests
5. Dyed Drift Experiment

The U of M Test Program began in 1973 as a multi-year impact assessment. The tower performance experiments began in 1975 with an initial complete characterization of the cooling tower emission ("Initial Characterization"). This was followed by a period of continuous monitoring ("Continuous Monitoring Phase"), interspersed with seasonal periods of intensive testing ("Seasonal Intensive Tests"). The experimental program concluded with the conduct of the "Dyed Drift Test" by APL in the early summer of 1977.

Ambient meteorological data were obtained from three levels of a 100-meter meteorological tower to support these studies. Furthermore, during the "Initial Characterization" of the cooling tower during the "Seasonal Intensive Tests" and during the "Dyed Drift Experiment", upper air soundings were taken to support the operation.

Much of the reporting of data is contained in the periodic reports of the various participants. A catalog of all data acquired to date was issued in the fall of 1977 as Chapter VI of Reference 3-1. Very little new data have become available since that time.

The quantity of available data is quite large. Samples of the data collected by the various participants during the different phases of the operation are presented with the test descriptions.

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UNIVERSITY OF MARYLAND PLANT RESEARCH PROGRAM

In the fall of 1972 and spring of 1973, 12 research sites were selected in the area surrounding the cooling towers under construction at the Chalk Point Generating Station shown in Fig. 3-1. It was of primary interest that there be four sites at each of three radii located at one, three and six mile distances from the towers. Also, the sites were to be located along reasonably straight lines from the towers in the north, east, south and west directions. This field design was selected because the data could be analyzed in terms of distances (three levels) and directions (four levels). The sites were located on soils which are considered to have good drainage and have a history of high agricultural productivity.

Each of the research sites shown in Fig. 3-2 is approximately 0.4 acres in area, fenced and under the total control of the research staff. Each site was equipped with three dust collectors, three sulfation plates and one rain gauge. Each site was partitioned in the following manner: (1) plots 16' by 25' with three replications were established for tobacco, corn, soybeans, and small grains; (2) a soils research plot approximately 30' by 30' was designated and kept in its initial state for the duration of the project; (3) the Botany Department was assigned a plot approximately 10' by 105' for its program with native species; and (4) the remainder of the area was planted in fescue grass to reduce the level of maintenance for each site, improve the neatness of the sites, and to keep down dust, etc., while working at the sites.

In addition to the test work at the research site, the impacts on native vegetation were monitored at selected stands of trees in the vicinity of the plant and a set of spray test plots were established to permit the determination of the effects of metered brackish water sprays on crops, soils and native plants.

The University of Maryland work was coordinated by the Water Resources Research Center and is described in References 3-2 to 3-20 and 3-31.

Agronomy Department

The role of the Agronomy Department was to evaluate the influence of salt fallout on agricultural vegetation and soils. The objectives were:

1. to characterize the physical and chemical properties of soils in the area surrounding Chalk Point for the purpose of obtaining a base line of potential pollutants for site evaluation;

2. to monitor fallout from the cooling tower and the level and movement of such materials in the soils surrounding the plants;

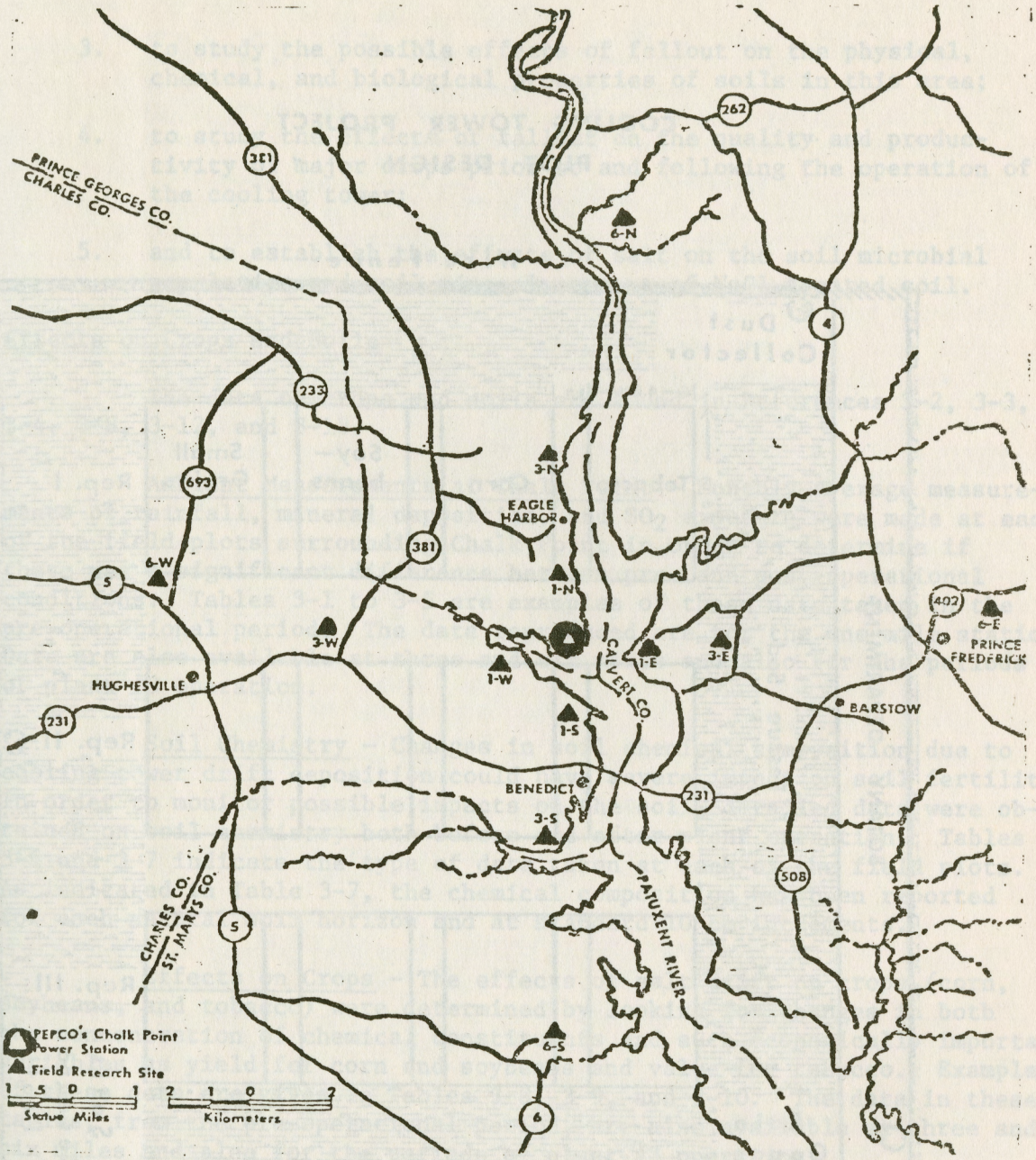


Figure 3-1. Area map indicating the location of the twelve research sites in relation to the Chalk Point Cooling Towers. (Reproduced from PPSP-CPCTP-6)

COOLING TOWER PROJECT
PLOT DESIGN

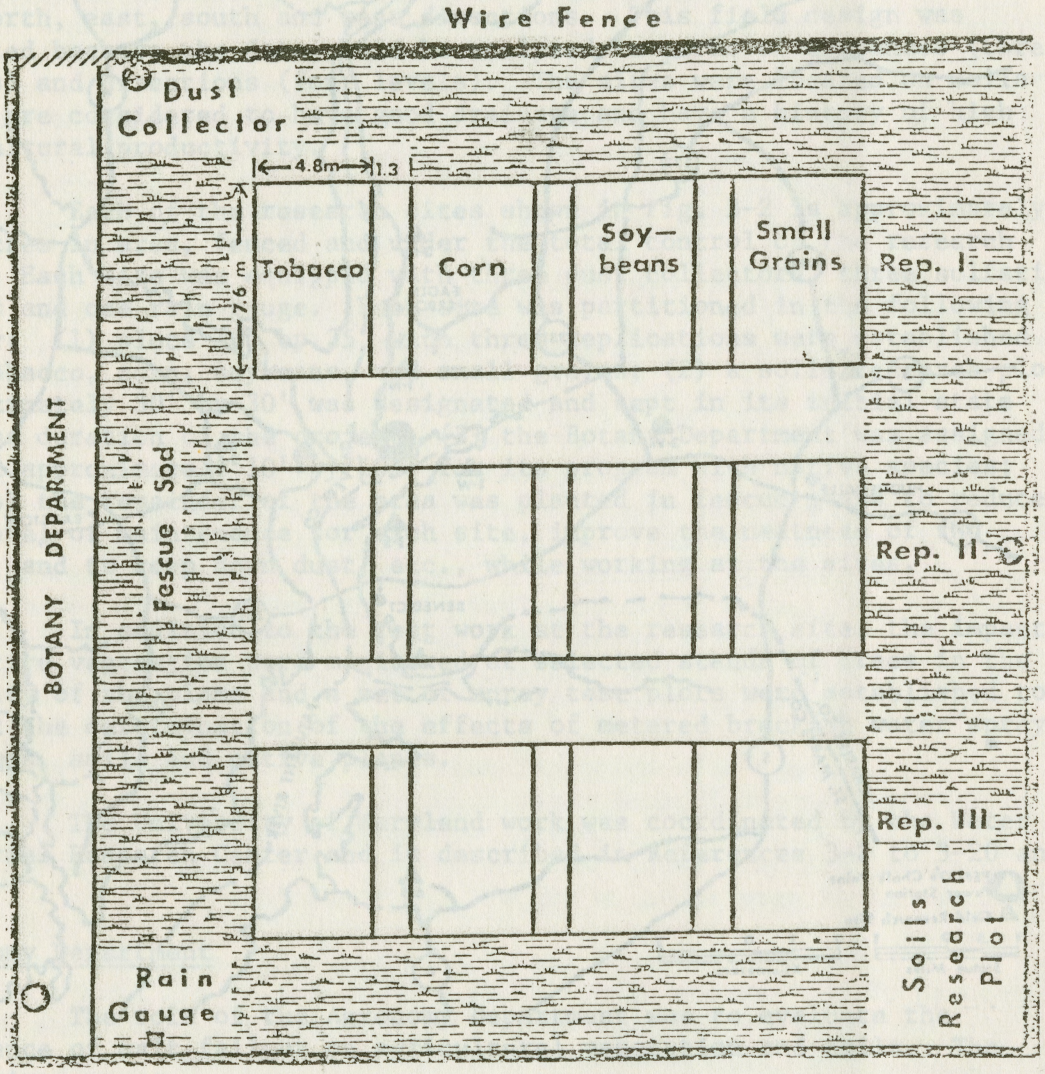


Figure 3-2. Diagram for research and monitoring sites in Chalk Point area. (Reproduced from PPSP-CPCTP-6)

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3. to study the possible effects of fallout on the physical, chemical, and biological properties of soils in this area;

4. to study the effects of fallout on the quality and productivity of major crops prior to and following the operation of the cooling tower;

5. and to establish the effects of salt on the soil microbial population and soil mineral content of NaCl treated soil.

Effects on Crops and Soils

The data on crops and soils are found in References 3-2, 3-3, 3-4, 3-8, 3-12, and 3-18.

Ambient Measurements at Chalk Point - Monthly average measurements of rainfall, mineral deposition, and SO_2 exposure were made at each of the field plots surrounding Chalk Point in order to determine if there was a significant difference between pre- and post-operational conditions. Tables 3-1 to 3-5 are examples of these data taken in the pre-operational period. The data reproduced are for the one-mile stations. Data are also available at three and six miles and also for the periods of plant #3 operation.

Soil Chemistry - Changes in soil chemical composition due to cooling tower drift deposition could have severe impact on soil fertility. In order to monitor possible impacts on the soil, detailed data were obtained on soil chemistry both before and after plant operation. Tables 3-6 and 3-7 indicate the type of data taken at each of the field plots. As indicated in Table 3-7, the chemical composition has been reported for each natural soil horizon and at standard 10 cm increments.

Effects on Crops - The effects of salt drift on crops (corn, soybeans, and tobacco) were determined by looking for changes in both the concentration of chemical constituents and such economically important variables as yield for corn and soybeans and value for tobacco. Examples of these data are given in Tables 3-8, 3-9, and 3-10. The data in these tables, from the pre-operational period, are also available at three and six miles and also for the periods of plant #3 operation.

Simulated Salt Drift Studies

Soil Measurements - This type of study consisted of following the changes in chemical composition of soil plots after controlled application of salt to the soil surface. This provided data on the accumulation of salt in Chalk Point soil types. An example of these data is found in Figure 3-3.

Table 3-1 Sodium analysis of water from the dustfall collectors at the Chalk Point Project. *

Site Code	April	May	June	July	August	September	October
	mgNa m^{-2} $month^{-1}$						
	1.6 kilometer radius (1 mile)						
1-N	N.S.[2/]	N.S.	N.S.	13.324	42.166	17.745	33.374
1-E	48.751	32.212	32.212	14.220	62.848	13.077	44.816
1-S	47.329	27.853	33.511	17.868	40.250	15.704	33.427
1-W	97.100	30.605	30.914	9.522	45.629	16.508	34.252
Mean	64.393	30.223	32.212	13.734	47.723	15.759	36.467

Table 3-2 Chloride analysis of water from the dustfall collectors at the Chalk Point Project. *

Site Code	April	May	June	July	August	September	October
	mg Cl $meter^{-2}$ $month^{-1}$						
	1.6 kilometer radius (1 mile)						
1-N	N.S.[2/]	N.S.	N.S.	32.769	121.955	38.828	88.002
1-E	94.349	50.699	71.936	63.497	117.380	22.042	102.717
1-S	90.052	55.645	61.611	46.773	93.505	32.429	112.897
1-W	183.906	61.828	50.080	33.387	101.320	45.505	73.535
Mean	122.769	56.209	61.209	44.106	108.540	34.701	94.288

Table 3-3 The quantity of water insoluble material from the dustfall collectors. The values reported represent a mean of three determinations (1973). *

Site Code	May	June	July	August	September	October
	grams of particulate matter $meter^{-2}$ $month^{-1}$					
	1.6 kilometer radius (1 mile)					
1-N	N.S.[2/]	N.S.	9.818	10.367	7.716	5.727
1-E	7.741	3.504	6.923	14.802	2.468	4.721
1-S	0.690	2.051	2.731	4.541	3.372	2.073
1-W	1.443	1.690	4.725	5.333	2.888	2.992
Mean	1.291	2.415	6.049	8.761	4.111	3.878

Table 3-4 Precipitation in form of rainfall from June through December 1973 at locations surrounding the cooling tower.

(From PPSP-CPCTP-6)

Site Code[1/]	Monthly Precipitation in Inches							
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total[2/]
	1.6 kilometer radius (1 mile)							
1-N	3/	0.99	8.09	0.72	1.26	1.90	0.64	13.60
1-E	2.11	1.72	8.68	0.80	1.15	0.86	0.77	16.10
1-S	3.00	1.54	9.58	0.84	1.34	2.00	0.43	18.73
1-W	1.62	1.38	10.53	0.91	1.69	2.07	0.53	18.73
Mean	2.24	1.41	9.22	0.82	1.36	1.71	0.59	17.35

Table 3-5 Estimation of the atmospheric sulfur dioxide content in 1973. Each value represents a mean of three replicates. *

Site Code	April	May	June	July
	mg SO_3/100cm/day			
	1.6 kilometer radius (1 mile)			
1-N	N.S.[1/]	N.S.	N.S.	0.19
1-E	0.21	0.14	0.21	0.16
1-S	0.17	0.03	0.09	0.08
1-W	0.19	0.06	0.03	0.11
Mean	0.19	0.08	0.11	0.13

*Tables excerpted from University of Maryland Agronomy Department Annual Report for 1973-1974.

Table 3-6. Description of Soil Profile, Site 1-North

(Reproduced from PPSP-CPCTP-6)

Lakeland loamy sand
S75Md16-1

Horizon	Depth cm	Depth in	Description
Ap	0-10	(0-4)	Reddish yellow and strong brown (7.5 YR 6/8, 5/6) loamy sand; structureless, single grain; loose; strongly acid; clear, smooth boundary.
C1	10-13	(4-5)	Yellow (10 YR 7/8) sand; structureless, single grain; loose; strongly acid; abrupt, smooth boundary.
IIApb	13-32	(5-13)	Yellowish red (5 YR 4/6) and strong brown (7.5 YR 5/6) loamy sand; structureless, single grain; loose; strongly acid; abrupt, smooth boundary.
IIC2	32-36	(13-14)	Brownish yellow (10 YR 6/8) loamy sand; structureless, single grain; loose; strongly acid; abrupt, smooth boundary.
IIC3	36-52	(14-21)	Yellowish red (5 YR 4/8) sandy laom; structureless; single grain; loose; very strongly acid; abrupt, smooth boundary.
IIC4	52-61	(21-24)	Brownish yellow and brown (10 YR 6/8, 5/3) with few, fine, and distinct strong brown (7.5 YR 5/8) mottles; sand; structureless, single grain; loose; strongly acid; abrupt, smooth boundary.
IIC5	61-107	(24-42)	Strong brown (7.5 YR 5/6) sandy loam; some banding of sandy clay loam (band from 86-96 cm); weak, subangular blocky structure with platy bands; friable; strongly acid; abrupt smooth boundary.
IIC6	107-121	(42-48)	Strong brown (7.5 YR 5/6) and yellowish red (5 YR 4/8) sandy loam; structureless, single grain; loose; strongly acid.
IIIApb	121-139	(48-55)	Grayish brown and dark gray (10 YR 5/2, 4/1) and strong brown (7.5 YR 5/8) sandy loam; structureless, single grain; loose; strongly acid.
IIIC7	139-150	(55-59)	Reddish yellow (7.5 YR 6/8) loamy sand; structureless, single grain; loose; medium acid.

Location: Prince Georges County; 2 miles north of Benedict, about 1.0 mile north of main Pepco plant (Cooling Tower Site).

Vegetation: Scrub pine; fallow 1973
Parent Material: Sandy Coastal Plain sediments; material is mixed because of grading operations
Physiography: Upland
Elevation: 80 feet
Slope: Nearly level (less than 1%)
Drainage: Well
Erosion: Disturbed area
Permeability: Rapid
Root distribution: Few below Ap horizon
Moisture: Moist
Ground water: Deep (greater than 60 inches)
Described by: D.C. Wolf and J.E. Foss
Date: 10/24/73
Remarks: This profile is disturbed in the upper 139 cm; the horizons are mixed with A, B, and C material from soils in the immediate vicinity. Although a series cannot be identified from this mixed profile, it does approximate the Lakeland series in physical characteristics. Concretions (5% by volume) are present at depths of 38 to 50 cm.

Table 3-7. Chemical Analysis and Reaction of Soil Samples from the 1-North Site (1973)
(Reprinted from PPSP-CPCTP-6)

Depth (cm)	pH (1:1)	Mg	P	K	Ca	Na
			ppm			
Soil Profile						
0- 10	5.4	95	111	52	90	16
10- 13	5.2	51	63	27	30	16
13- 32	5.3	104	48	24	80	16
33- 36	5.3	77	47	27	60	18
36- 52	5.0	60	44	16	20	17
52- 61	5.2	38	74	17	30	16
61-107	5.4	97	21	32	100	20
107-121	5.5	89	16	26	80	15
121-139	5.4	74	19	27	90	15
139-150	5.7	56	23	16	90	14
Soil Column						
0- 10	5.3	84	112	46	75	16
10- 20	5.2	88	51	26	55	16
20- 30	5.4	86	50	24	70	16
30- 40	5.2	47	50	22	40	17
40- 50	5.0	47	44	18	25	15
50- 60	5.2	34	60	18	30	16
60- 70	5.2	58	29	34	40	19
70- 80	5.4	79	23	31	75	17
80- 90	5.3	115	14	34	85	18
90-100	5.2	133	13	37	90	20

Table 3-8. Nutrient content and metabolic index of soybean plant tissue (1973). (From PPSP-CPCTP-6)

Site[3]	Sample[2] Date	Nutrient Content %P	%K	%Ca	%Mg	%Na	%Cl	Metabolic Index
1.6 kilometers (one mile) radius								
1-N	1	0.26	2.5	0.89	0.84	0.07	0.20	16.7
	2	0.28	2.0	1.06	0.74	0.08	0.06	30.5
1-E	1[4]	-	-	-	-	-	-	-
	2	0.26	2.7	1.01	0.74	0.07	0.08	32.1
1-S	1	0.23	2.6	1.27	0.81	0.08	0.08	29.6
	2	0.29	2.3	1.41	0.55	0.07	0.06	33.9
1-W	1	0.24	2.8	1.33	0.66	0.07	0.20	18.2
	2	0.28	1.7	1.41	0.65	0.08	0.10	23.3
Means	1	0.25	2.6	1.16	0.77	0.07	0.16	21.5
	2	0.28	2.2	1.22	0.67	0.07	0.07	30.0

Table 3-9. Yields and moisture contents of grain from corn and soybean plots (1973). (Excerpt from U of M Annual Report 1973-1974)

Site	Corn Yield[a] Bu A^{-1}	Corn Moisture (%)	Soybeans Yield[c] Bu A^{-1}	Soybeans Moisture (%)
1.6 Kilometer (one mile) Radius				
1-N	(18.1)[b]	(27.0)[b]	11.9	10.7
1-E	94.1	18.1	13.6	12.7
1-S	163.5	17.9	42.6	11.5
1-W	125.7	19.9	34.8	11.7
Mean ($\bar{x}$)	127.8	18.6	25.7	11.7

Table 3-10. Yield, average price, value, total nitrogen and total alkaloid contents of cured tobacco (1973). (Excerpt from U of M Annual Report 1973-1974).

Site	Yield[a] lb A^{-1}	Price[b] \$ 100 lbs^{-1}	Value[c] \$ A^{-1}	Total Nitrogen (%)	Total Alkaloids (%)
1.6 Kilometer (one mile) Radius					
1-N	1151	73.98	850	2.90	1.49
1-E	2039	81.51	1662	3.80	3.06
1-S	2249	78.60	1768	4.46	2.65
1-W	2118	78.85	1670	3.82	2.62
Mean ($\bar{x}$)	1889	78.24	1480	3.74	2.46

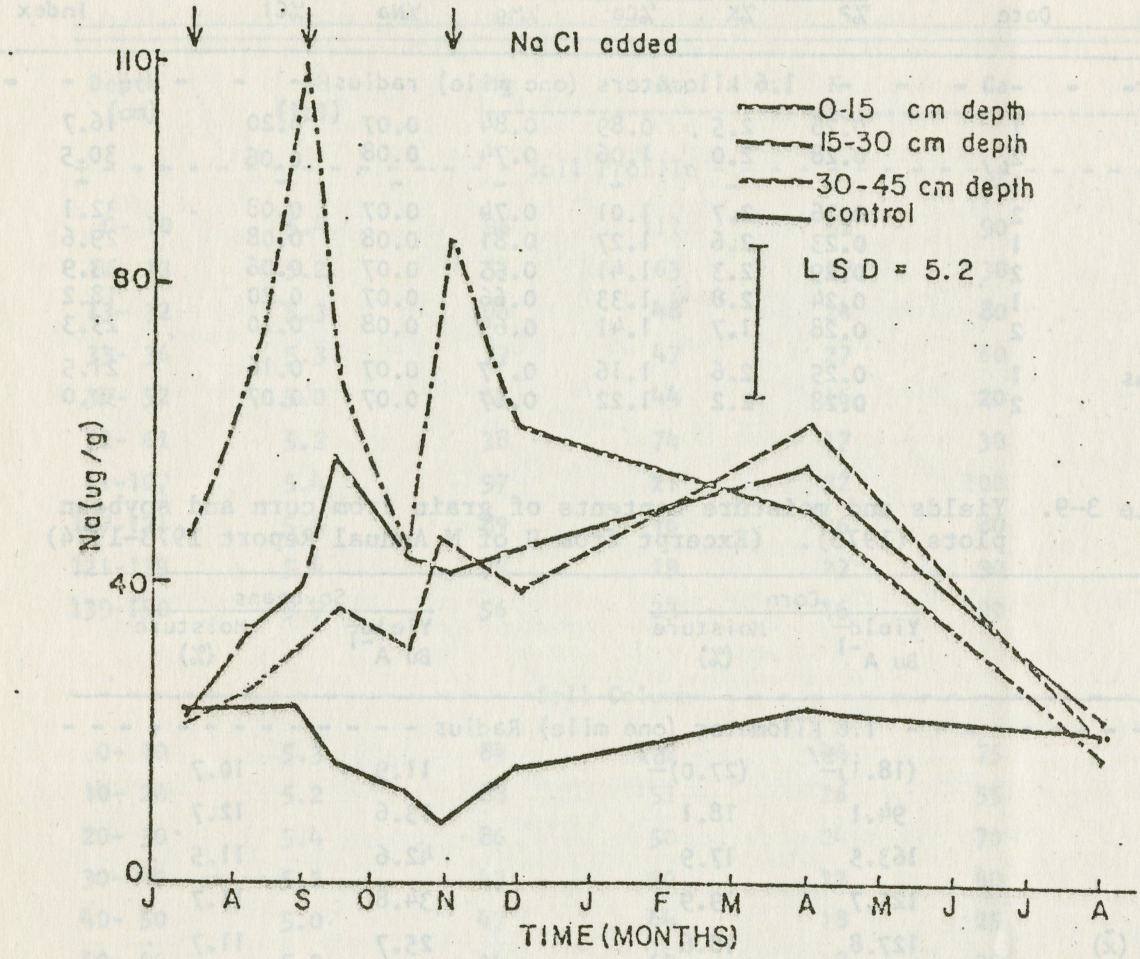


Figure 3-3. The effect of three additions of 10g $NaCl/m^2$ on the extractable Na levels at three depths in a Lakeland loamy sand.

(Reproduced from Reference 3-32)

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Crop Effects - Test plots of corn, soybeans, and tobacco were exposed to salt either as additions to the soil or as a saline solution aerosol. The crops were then analyzed in the same manner as those grown in the field plots described earlier. Examples of these data may be found in Tables 3-11, 3-12, and 3-13.

Botany Department

The research being conducted by the Botany Department was directed toward non-agronomic species of plants, with major emphasis on native and cultivated perennial species. This portion of the study was divided into three major areas:

1. The gathering of long-term monthly baseline Na^+ and Cl^- data from leaves of selected local vegetation surrounding the power plant.

2. The monitoring and maintenance of the six tree farms which were installed in selected 0.4 acres fenced field plots in order to study symptom evaluation, allow for chemical analyses and determine species sensitivity to salt drift.

3. The determination of foliar symptoms of saline aerosol injury under field conditions.

Sites used in the Botany Research are shown as Figures 3-4 and 3-5.

Studies of Native Vegetation

The studies of the effects of salt drift on native vegetation follow the same pattern as the crop and soils work described earlier. The data from the native vegetation studies can be found in References 3-5, 3-7, 3-8, 3-11, 3-16 and 3-31.

Ambient Effects at Chalk Point - Determination of the effects of actual Chalk Point emissions on the native vegetation was made through determination of changes in the sodium and chloride levels in thirteen stands of native tree types surrounding the power plant site. Tables 3-14 and 3-15 are examples of these types of data.

Simulated Salt Drift - In an effort to establish a dose response relationship between saline aerosol deposition and damage to vegetation, a number of different species of trees and shrubs were exposed to saline water sprays. The only species showing significant damage was dogwood. Tables 3-16, 3-17, and 3-18 give examples of the data on the chemical and physical changes associated with the spraying. Table 3-19 shows data depicting the range of salinity of the water used in the spray test program.

Table 3-11. Effects of salt spray applications on the nutrient contents and metabolic index in soybean leaves. [a] (1973) (U of M Annual Report 1973-1974)

Salt (NaCl) Treatments [c] kg ha^{-1}wk^{-1}	Nutrients [b] Ca	Mg	K	P	Cl	Na	Metabolic Index [d] (I)
	%						
0	1.30	0.50	1.90	0.33	0.069	0.065	32.10
1.82	1.05	0.37	1.70	0.26	0.260	0.078	9.88
3.64	1.49	0.56	2.10	0.36	0.503	0.114	7.23
7.28	1.35	0.53	2.00	0.34	0.689	0.142	5.08
14.56	1.60	0.67	2.20	0.42	1.310	0.211	3.21
Mean	1.36	0.58	2.00	0.34	0.567	0.122	11.6
LSD(.05)	N.S. [e]	0.18	N.S.	N.S.	0.114	0.091	9.54
CV(%)	19.4	22.5	19.1	20.4	13.0	48.8	53.4

a/ Sampled from entire plant canopy following last treatment.

b/ Average of four replications. Expressed as percent dry weight. to convert to ppm multiply by 10^4.

c/ Applied as concentrated sodium chloride solution spray on a weekly basis for eight weeks. To convert to lbs. A^{-1}, divide by 1.1.

d/ Determined by dividing the $\sum$ Ca + Mg + K + P by the $\sum$ Cl + Na.

e/ N.S. indicates nonsignificant difference between values.

Table 3-12. Effect of salt spray applications on yields and moisture levels of corn and soybeans (1973). (U of M Annual Report 1973-1974)

Salt (NaCl) Treatments [a] kg ha^{-1} wk^{-1}	Soybeans Yield [b] Bu A^{-1}	Soybeans Moisture (%)	Corn Yield [c] Bu A^{-1}	Corn Moisture (%)
0	47.5	13.2	137.0	20.9
1.82	49.4	13.4	122.7	20.8
3.64	47.5	14.1	122.2	20.9
7.28	41.2	13.3	102.0	21.2
14.56	39.0	13.6	84.0	20.8
Mean ($\bar{x}$)	44.8	13.5	113.6	20.9
LSD (.05)	3.9	N.S. [d]	24.2	N.S.
CV (%)	5.8	3.9	13.8	3.5

a/ Applied as concentrated sodium chloride solution spray on weekly basis for eight weeks. To convert to lbs A^{-1} divide by 1.1.

b/ To convert Bu A^{-1} to metric ton ha^{-1} for soybeans, divide by 14.66.

c/ To convert Bu A^{-1} to metric ton ha^{-1} for corn, divide by 15.74.

d/ N.S. indicates nonsignificant differences between values.

Table 3-13. Effect of Salt Spray Treatments on Yield, Price, Value, Total Nitrogen and Total Alkaloids of Cured Tobacco (1973). (U of M Annual Report 1973-1974)

Salt (NaCl)[a/] Treatment kg ha^{-1} wk^{-1}	Yield[b/] lbs A^{-1}	Price[c/] \$100 lbs^{-1}	Value[d/] \$ A^{-1}	Total Nitrogen (%)	Total Alkaloids (%)
0	1925	84.25	1683	3.05	2.87
1.82	2042	84.79	1732	2.98	2.81
3.64	2163	85.04	1842	2.94	3.06
7.28	2053	84.33	1733	2.75	2.64
14.56	2023	84.26	1706	3.08	2.86
Mean ($\bar{x}$)	2056	84.53	1739	2.96	2.84
LSD (.05)	N.S.[e/]	N.S.	N.S.	N.S.	N.S.
CV (%)	7.8	0.8	8.3	11.1	7.6

[a/] Applied as concentrated sodium chloride solution spray on weekly basis for eight weeks. To convert to lbs A^{-1}, divide by 1.1.

[b/] To convert to kg ha^{-1}, multiply by 1.1.

[c/] To convert to \$100 kg^{-1}, multiply by 2.2.

[d/] To convert to \$ ha^{-1}, divide by 2.5.

[e/] N.S. indicates non-significant.

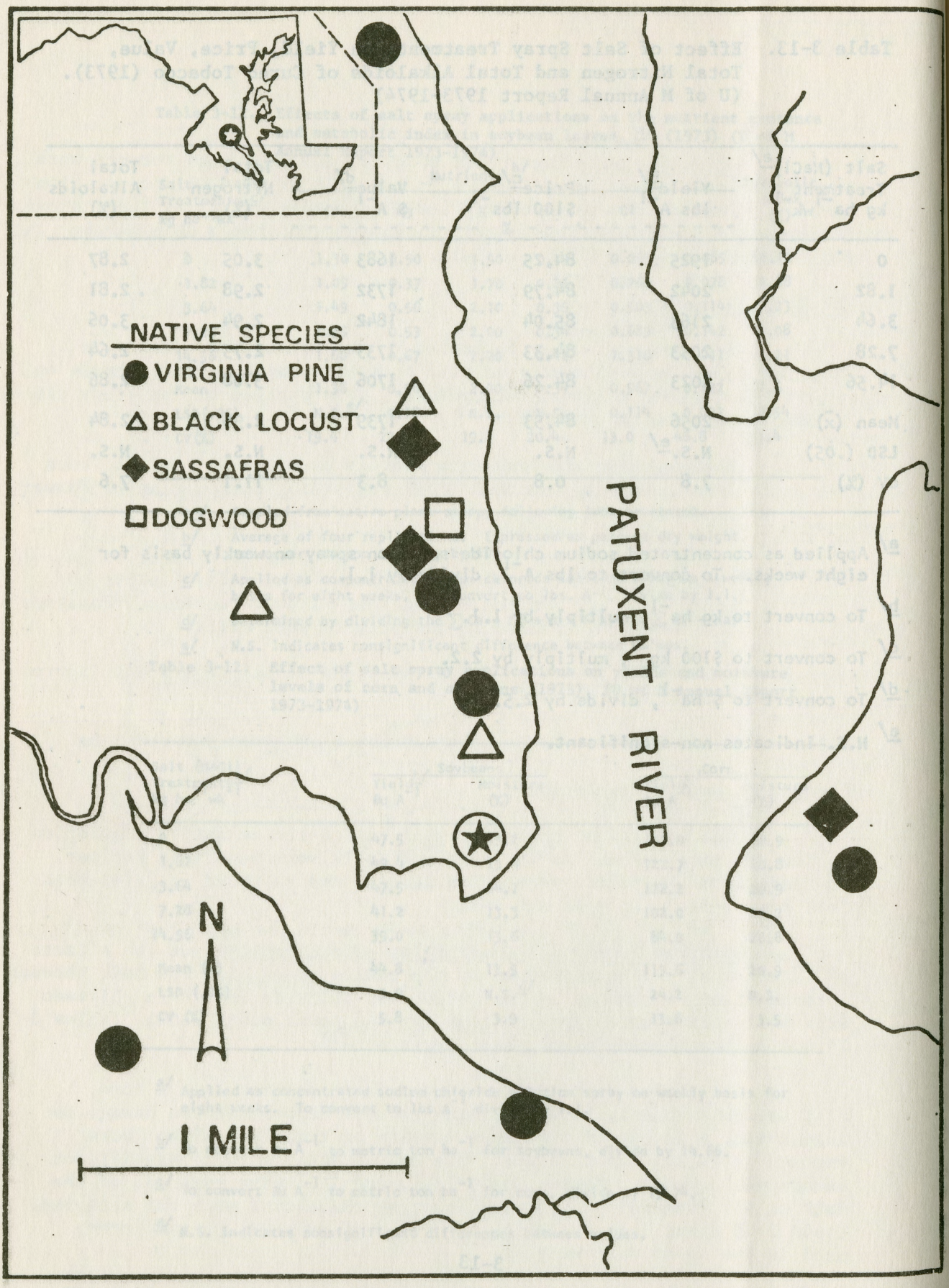


Figure 3-4. University of Maryland Botany Department Native Species Sampling Sites. (Reproduced from PPSP-CPCTP-7).

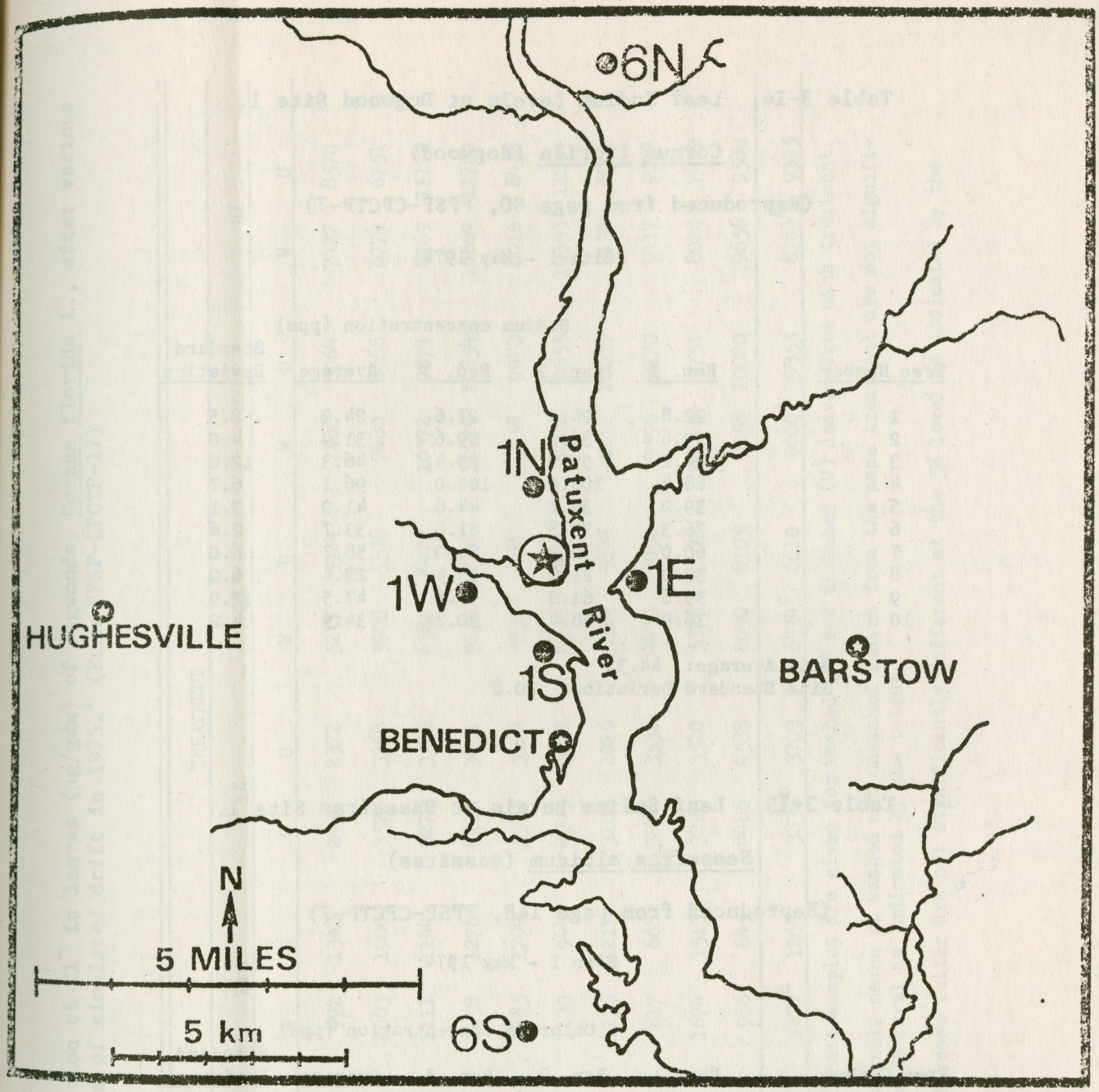


Figure 3-5. Location of University of Maryland Botany Department Tree Farm Sites. (Reproduced from PPSP-CPCTP-7)

Table 3-14. Leaf Sodium Levels at Dogwood Site 1.

Cornus florida (dogwood)

(Reproduced from page 80, PPSP-CPCTP-7)

Site 1 - May 1974

	Sodium concentration (ppm)				
Tree Number	Rep. 1	Rep. 2	Rep. 3	Average	Standard Deviation
1	22.8	24.2	27.6	24.9	2.5
2	29.6	36.6	29.6	31.9	4.0
3	44.2	59.2	35.4	46.3	12.0
4	88.4	100.0	100.0	96.1	6.7
5	39.2	39.2	44.6	41.0	3.1
6	36.3	33.8	31.0	33.7	2.6
7	60.0	52.2	64.0	58.7	6.0
8	30.0	21.8	33.4	28.4	6.0
9	35.6	61.2	45.6	47.5	12.9
10	36.0	38.4	30.2	34.9	4.2

Site Average: 44.3
Site Standard Deviation: 20.8

Table 3-15. Leaf Sodium Levels at Sassafras Site 1.

Sassafras albidum (sassfras)

(Reproduced from page 148, PPSP-CPCTP-7)

Site 1 - May 1974

	Chloride concentration (ppm)				
Tree Number	Rep. 1	Rep. 2	Rep. 3	Average	Standard Deviation
1	188.1	190.9	189.5	189.5	1.4
2	137.5	137.5	137.5	137.5	----
3	192.3	199.4	193.1	194.9	3.9
4	134.2	148.6	141.4	141.4	7.2
5	149.1	181.1	184.6	171.6	19.6
6	174.5	174.5	174.5	174.5	----
7	219.1	213.5	217.0	216.5	2.8
8	144.8	144.8	148.4	146.0	2.1
9	154.2	147.2	161.3	154.2	7.0
10	252.8	254.2	252.8	253.3	.8

Site Average: 177.9
Site Standard Deviation: 36.8

Table 3-16. Concentration of Cl^- in leaves (µg/gdw) of dogwoods, Cornus florida L., after various treatments of simulated drift in 1975.[1] (From PPSP-CPCTP-17)

Tree No.	TREATMENT											
	NS		Tap		1X		2X		3X		4X	
	W	U	W	U	W	U	W	U	W	U	W	U
1	1550	802	992	1342	2444	2372	5217	5924	7400	8064	7427	8570
2	2219	1268	2003	1900	3578	3368	5900	5306	7480	8068	6774	6751
3	1272	712	1111	1144	3273	3578	6382	6472	10372	9874	8769	11172
4	1176	874	1158	1278	4208	3851	9258	10014	10924	10854	10869	11700
5	1450	1233	1685	1794	5575	5366	7030	7268	9058	9970	8016	8458
6	1215	504	1130	944	4945	4830	7546	6988	7048	7655	10353	12244
7	762	956	1236	1217	3100	2026	5514	5844	10252	10000	8138	8964
8	909	689	817	668	3462	3532	4430	5050	9596	9270	9417	9094
9	616	824	1674	1513	3228	3520	5373	5132	8610	9751	8022	7419
10	859	810	966	845	4486	4588	8090	8105	9258	10020	9656	9580
Mean[2,3]	1203[a]	867	1277[a]	1264	3830[b]	3703	6474[c]	6610	9000[d]	9353	8744[d]	9395

[1]The averages of duplicate samples are given for washed (W) and unwashed (U) leaves from each treatment.

[2]Except for the NS control, means of washed and unwashed leaves from the same treatment are not significantly different at the 5% level as indicated by the t-test.

[3]Means followed by the same letter are not significantly different at the 5% level as indicated by the SNK test.

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Table 3-17. Concentration of Na^+ in leaves (µg/gdw) of dogwoods, C. florida after treatments of simulated drift in 1975.[1] *

Group No.	TREATMENT					
	NS	Tap	1X	2X	3X	4X
Ix	130	159	208	618	1686	1728
Iy	185	306	180	655	1386	1944
IIx	190	274	270	698	1489	2269
IIy	213	159	324	636	1112	1711
Mean[2]	180[a]	224[a]	246[a]	652[b]	1418[c]	1913[d]

[1]Results of duplicate samples (x,y) from each random group of trees are reported.

[2]Means followed by the same letter are not significantly different at the 5% level as indicated by the SNK test.

Table 3-18. Percentage of leaves injured on dogwood, Cornus florida L., after various treatments of simulated drift in 1975.[1] *

Tree No.	TREATMENT					
	NS	Tap	1X	2X	3X	4X
1	1.0	0.0	0.0	8.6	34.4	57.6
2	0.0	0.0	4.4	2.8	25.0	16.0
3	0.0	0.0	0.0	5.6	10.7	26.5
4	0.0	0.0	0.0	1.5	7.4	7.4
5	0.0	0.0	0.5	3.7	2.7	6.5
6	0.0	0.0	0.0	1.2	21.2	5.4
7	0.0	0.0	0.0	6.9	45.3	17.7
8	1.0	0.0	0.0	3.7	19.6	34.1
9	0.7	1.8	0.0	8.6	16.7	100.0
10	0.0	0.0	5.0	14.3	11.4	19.6
Mean[2]	0.3	0.2	1.0[a]	5.7[b]	19.4[c]	29.1[c]

[1]Data from July 24, 1975.

[2]Means followed by the same letter are not significantly different at the 5% level as indicated by the SNK test.

Table 3-19. Analyses of cooling tower basin water (CTBW) and tap water[1] used in 1975 and 1976.*

Sample	CONCENTRATION (ppm)						
	Cl^-	Na^+	K^+	Ca^{++}	Mg^{++}	NO_3^-	Total Soluble Salts
CTBW-No.1-1975	4497	2140	860	147	125	0.1	8,685
CTBW-No.2-1975	8734	4320	165	244	232	1.0	13,886
CTBW-1976	6300	3150	166	242	162	6.9	10,200
Tap Water-1975	2.8	20	1.2	30	0.8	0.8	200
Tap Water-1976	2.5	1.4	1.7	30	0.5	0.6	127

[1]Tap water was collected at the Tobacco Experimental Farm.

*From PPSP-CPCTP-17, page 65

PRELIMINARY DATA COLLECTION

During the period beginning May 31, 1974 and continuing through October 1975, ESC collected preliminary data at Chalk Point. Ground level salt deposition data and ground level drift concentration data were taken throughout this period using the airborne particle sampler and sensitive paper equipment. These data were intended to provide prove-in of equipment and method and to establish sea salt background levels. In addition source term data, meteorological data and some plume photography were also obtained.

Salt Deposition Data

In summary, there are 21 sampling periods of APS data displayed as sea salt deposition and 180 samples of APS data displayed as sea salt concentration. Each sampling period encompasses several hours of data acquisition. The salt concentration data, while primarily of periods in which Unit #3 was inoperable, also encompass periods of time in which Unit #3 was operable. Samples of the data acquired appear as Tables 3-20 and 3-21. Selected sites of Figure 3-1 were used.

Meteorological Data

Beginning in July 1975, ESC assumed responsibility for operation of and data reduction from the meteorological tower at Chalk Point. Approximately three months' data were obtained and reported as preliminary data. While the data were archived as 30-minute averages of the variable at the three levels of the tower, Table 3-22 presents the format for weekly meteorological statistics as reported by ESC.

Drift Data

As a part of the preliminary data and preparatory to the Initial Characterization Tests of tower emissions, ESC acquired data relative to the source characteristics. The data are presented in two ways. Table 3-23 presents a sample of the drift mass flux as a function of droplet size. It is one of 18 such data samples acquired during June and July 1975. Table 3-24 presents a sample of drift mass concentration as a function of droplet size. This is one of eleven samples taken during the period. Since all of these data were taken prior to the Initial Characterization Tests, it was not intended for use in model evaluation. It has been valuable in estimating levels of deposition to be expected in subsequent test periods.

Table 3-20

SAMPLE OF SEA SALT CONCENTRATION DATA

(Synthesized from PPSP-CPCTP-9)

A. TABLE OF ABBREVIATIONS:

ST-STATION NUMBER
CHI-MASS OF SEA SALT PER UNIT VOLUME OF AIR (MICROGRAMS/CU.M)
VOLUME-SAMPLED AIR VOLUME IN CUBIC METER
NET SODIUM-COLLECTED MASS OF SODIUM MINUS AVERAGE PROCEDURAL BACKGROUND (MICROGRAMS)
WINDSPEED IN KM/H
DRYBULB TEMP.&DIFF.-DRY BULB TEMPERATURE AND DRY BULB MINUS WET BULB TEMPERATURE (FAHRENHEIT)
RELHM-RELATIVE HUMIDITY-BASED ON U.S. WEATHER BUREAU BULLETIN # 1071
C-COMMENT CODE: 0-GOOD RUN
1-LIGHT RAIN (SAMPLE SALVAGED)
2-HEAVY RAIN (SAMPLE RUINED)
3-LIGHT SNOW (SAMPLE SALVAGED)
4-HEAVY SNOW (SAMPLE RUINED)
5-FOG
6-BUGS ON MESH
7-DUST
8-WHITE CAPS VISIBLE OFF COAST
9-LOSS OF MESH
10-OTHER COMMENTS OR A COMBINATION OF ABOVE COMMENTS, SEE RAW DATA SHEETS

B. DATA SAMPLES:

RUN# 4 DATE: 6/13/1974

ST #	CHI	VOLUME CU.M	NET SODIUM	TIME START/END	WINDSPEED START/END	WIND DIR.	DRYBULB TEMP.&DIFF. START/END	C	RELHM ST/ED
3N	0.04	121.5	1.6	1201/1535	1.9/ 3.0	S/ E	80.0&15.0/82.0&16.0	9	44/42
1N	0.04	330.6	4.1	1249/1615	3.8/ 0.0	NNE/SSW	78.0&14.0/77.0&15.0	0	46/42
1E	0.04	190.1	2.5	1402/1723	5.9/ 4.5	SW/ESE	80.0&16.0/80.0&14.0	9	41/47

NO UNIT OPERATION PRIOR TO OR DURING TEST ON TEST DATE.

RUN# 5 DATE: 6/19/1974

ST #	CHI	VOLUME CU.M	NET SODIUM	TIME START/END	WINDSPEED START/END	WIND DIR.	DRYBULB TEMP.&DIFF. START/END	C	RELHM ST/ED
6W	0.02	282.0	1.3	1042/1327	5.2/ 7.7	SSW/ SW	79.0&13.0/ 0.0& 0.0	0	50/ 0
3N	0.01	286.7	0.7	1135/1405	8.1/ 7.4	SSW/ SW	0.0& 0.0/ 0.0& 0.0	0	0/ 0
1N	0.08	259.1	5.9	1227/1437	3.9/ 7.2	SSW/ SW	0.0& 0.0/ 0.0& 0.0	0	0/ 0

NO UNIT OPERATION PRIOR TO OR DURING TEST ON TEST DATE.

RUN# 6 DATE: 6/21/1974

ST #	CHI	VOLUME CU.M	NET SODIUM	TIME START/END	WINDSPEED START/END	WIND DIR.	DRYBULB TEMP.&DIFF. START/END	C	RELHM ST/ED
6W	0.05	335.2	5.2	1125/1700	8.5/ 6.6	SW/ SW	81.0& 9.0/86.0& 9.0	10	65/67
1N	0.09	175.4	4.8	1305/1625	8.7/11.1	SW/ SW	88.0&14.0/87.0&11.0	10	52/61
3E	0.13	151.5	5.9	1520/1745	14.6/10.8	SW/SSW	86.0& 9.0/87.0&10.0	9	67/64
1E	0.16	312.9	15.6	1448/1804	12.0/ 9.9	SSW/ SW	89.0&13.0/85.0&10.0	0	55/63

NO UNIT OPERATION PRIOR TO OR DURING TEST ON TEST DATE.

Table 3-21

SAMPLE OF SEA SALT DEPOSITION DATA

(Synthesized from PPSP-CPCTP-9)

A. TABLE OF ABBREVIATIONS:

ST-STATION NUMBER
DEP-SEA SALT DEPOSITION (KG/SQ.KM/MONTH)
NET SODIUM-COLLECTED MASS OF SODIUM MINUS AVERAGE,PROCEDURAL BACKGROUND(MICROGRAMS)
WINDSPEED IN KM/H
DRYBULB TEMP.&DIFF.-DRY BULB TEMPERATURE AND DRY BULB MINUS WET BULB TEMPERATURE (FAHRENHEIT)
REL HUMID-RELATIVE HUMIDITY-BASED ON U.S. WEATHER BULLITIN # 1071
NDT-SHOWN IN SOME WIND DIRECTION ENTRIES MEANS NO DATA TAKEN
C-COMMENT CODE: 0-GOOD RUN
1-LIGHT RAIN (SAMPLE SALVAGED)
2-HEAVY RAIN(SAMPLE RUINED)
3-LIGHT SNOW(SAMPLE SALVAGED)
4-HEAVY SNOW (SAMPLE RUINED)
5-FOG
7-DUST
8-WHITE CAPS VISIBLE OFF COAST
10-OTHER COMMENTS OR A COMBINATION OF ABOVE COMMENTS, SEE RAW DATA SHEETS

B. DATA SAMPLES:

RUN# 19 SPANNING FROM 5/21/1975 TO 5/22/1975

ST #	DEP	NET SODIUM	TIME START/END	WINDSPEED START/END	WIND DIR. START/END	DRYBULB TEMP.&DIFF. START/END	C	REL HUMID START/END
6W	1530.6	492.5	1342/1349	3.7/ 2.2	E/ W	87.8&10.8/86.0& 9.0	0	62/67
3N	77.2	24.8	1313/1320	1.5/ 3.0	SSE/ E	89.6&12.6/86.0& 9.0	0	57/67
1N	49.5	16.0	1407/1417	2.9/ 1.7	NNE/ESE	87.8&12.6/86.9& 9.9	0	56/64
3S	676.2	217.6	1447/1454	1.7/ 1.6	E/ S	86.9&11.7/87.8& 9.0	0	59/67
3E	472.9	151.6	1525/1527	1.9/ 3.2	WSW/ESE	87.8&10.8/87.8&10.8	0	62/62
1E	1123.2	360.2	1543/1545	4.5/ 7.0	SSE/ SE	87.8&11.7/87.8&10.8	0	59/62

RUN# 20 SPANNING FROM 6/19/1975 TO 6/20/1975

ST #	DEP	NET SODIUM	TIME START/END	WINDSPEED START/END	WIND DIR. START/END	DRYBULB TEMP.&DIFF. START/END	C	REL HUMID START/END
6W	378.5	119.7	1356/1338	1.7/ 2.9	SW/ NE	92.3& 9.9/84.2&10.8	0	66/60
3N	145.4	46.0	1328/1310	2.7/ 0.5	SSW/NNE	91.4& 9.9/86.9&12.6	0	66/56
1N	90.2	28.4	1434/1412	3.5/ 2.5	NNE/ NE	89.6&10.8/86.9&11.7	0	62/59
3E	203.2	65.7	1513/1527	4.8/ 3.6	SW/ENE	91.4&10.8/86.0&12.6	0	63/55
1E	220.6	71.2	1533/1544	0.4/ 0.8	SW/ENE	91.4&10.8/84.2&10.8	0	63/60

RUN# 21 SPANNING FROM 6/24/1975 TO 6/25/1975

ST #	DEP	NET SODIUM	TIME START/END	WINDSPEED START/END	WIND DIR. START/END	DRYBULB TEMP.&DIFF. START/END	C	REL HUMID START/END
6W	326.0	105.4	1345/1359	2.5/ 4.0	WSW/ E	93.2&12.6/88.7&10.8	0	58/62
3N	160.9	52.0	1317/1330	1.1/ 1.7	SW/NNE	87.8& 8.1/88.7&10.8	0	70/62
1N	636.7	206.1	1416/1432	3.1/ 1.5	S/ NE	92.3&11.7/89.6&12.6	0	61/57
3S	463.2	143.6	1353/1307	3.2/ 2.3	S/ENE	89.6&10.8/90.5&11.7	0	62/60
3E	481.6	155.6	1520/1533	5.2/ 3.3	SW/ E	91.4&13.5/91.4&14.4	0	55/52
1E	357.4	115.2	1538/1548	7.0/ 3.8	S/ N	91.4&14.4/87.8&11.7	0	52/59

Table 3-22. Sample of Meteorological Statistical Data*

CHALK POINT DATA REDUCTION DAYS 205-212 DATE 082175 PAGE 132

SUMMARY FOR CHALK POINT DATA BEGINNING YEAR 1975 DAY 205 TIME 15:18

INPUT RECORDS 342 OUTPUT INTERVALS 342

WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
7 METERS	7%	7%	7%	3%	8%	2%	0%	1%	2%	14%	14%	6%	5%	3%	4%	9%
50 METERS	3%	12%	10%	6%	9%	6%	0%	2%	2%	12%	16%	6%	3%	2%	2%	2%
100 METERS	13%	7%	4%	6%	10%	4%	2%	2%	10%	12%	8%	5%	2%	1%	2%	3%

HORIZONTAL WIND SPEED	0-2	2-4	4-7	7-10	> 10
7 METERS	65%	31%	2%	0%	0%
50 METERS	20%	52%	24%	2%	0%
100 METERS	23%	36%	26%	13%	0%

VERTICAL WIND SPEED	< -5	-5 < -1	-1 < -.2	-.2 < 0	0 < .2	.2 < 1	1 < 5	> 5
100 METERS	0%	0%	0%	2%	91%	6%	0%	0%

STABILITY SIGMA	A	B	C	D	E	F	G
7 METERS	45%	17%	26%	8%	2%	0%	0%
50 METERS	18%	10%	12%	26%	25%	5%	1%
100 METERS	10%	6%	11%	21%	29%	13%	7%
STABILITY - DT/DZ							
7-92 METERS	12%	11%	7%	22%	20%	16%	9%
50-92 METERS	39%	3%	3%	11%	19%	18%	4%

DEW-POINT ABOVE AMBIANT TEMPERATURE
10 METERS 0%
100 METERS 0%

*From PPSP-CPCTP-9

Table 3-23

DRIFT MASS FLUX AS A FUNCTION OF DROPLET SIZE

(Reproduced from PPSP-CPCTP-9)

Date and Time: June 27, 1975, 11:30 - 17:30 EDT
Measurement Mode: Point Measurement
Measurement Location: Level 358', Center
These data were acquired by: PILLS and SP

I	d' μm	d" μm	Δd μm	d_c μm	ΔF μg/m²s	ΔF/F %
1	10	30	20	20	5040	17.7
2	30	50	20	40	6220	21.9
3	50	70	20	60	5550	19.5
4	70	90	20	80	3710	13.1
5	90	110	20	100	2220	7.8
6	110	130	20	120	1690	6.0
7	130	150	20	140	1090	3.8
8	150	180	30	165	828	2.9
9	180	210	30	195	490	1.7
10	210	240	30	225	299	1.0
11	240	270	30	255	198	0.7
12	270	300	30	285	164	0.6
13	300	350	50	325	214	0.8
14	350	400	50	375	223	0.8
15	400	450	50	425	187	0.7
16	450	500	50	475	136	0.5
17	500	600	100	550	125	0.4
18	600	700	100	650	36.8	0.1
19	700	800	100	750	16.7	0.1
					$F = \Sigma\Delta F \simeq 28{,}500$	100.1*

*The summation of this column is not 100% due to rounding.

Time Mean Air Updraft Velocity and Air Temperatures

Updraft Velocity: 4.43 m/s
Wet Bulb Temperature: 38.3°C
Dry Bulb Temperature: Not Available

Mineral Mass Fluxes

Sodium Mass Flux: 231.9 $\frac{\mu g}{m^2 \cdot sec}$

Magnesium Mass Flux: 30.4 $\frac{\mu g}{m^2 \cdot sec}$

Basin Water Concentration: Sodium Concentration: 3000 mg/liter
Magnesium Concentration: 385 mg/liter

Observations: These measurements represent an average over approximately eight hours. The Unit 3 generated power was above 600 MW for 7 of these hours. The updraft air dry bulb sensor was not operating during this run.

Table 3-24. Drift Mass Concentration as a Function of Droplet Size

(Reproduced from PPSP-CPCTP-9)

Date and Time: July 7, 1975, 14:49 EDT
Measurement Mode: Point Measurement
Measurement Location: Level 200', 50' north of center
These data were acquired by: SP

I	d' μm	d" μm	Δd μm	d_c μm	P(d) #/μm·m³	Δx_i μg/m³
1	10	30	20	20	20000	1676
2	30	50	20	40	1650	1106
3	50	70	20	60	350	791
4	70	90	20	80	90	482
5	90	110	20	100	31	325
6	110	130	20	120	13	235
7	130	150	20	140	6.0	172
8	150	180	30	165	2.3	162
9	180	210	30	195	.82	95.5
10	210	240	30	225	.36	64.4
11	240	270	30	255	.20	52.1
						$\Sigma \simeq 5160$

Updraft air velocity and wet bulb/dry bulb temperature in the cooling tower were not acquired during this measurement.

INITIAL CHARACTERIZATION

The objectives of the initial characterization are the following:

1. characterization (i.e. measurement of the plume and drift descriptors) of the cooling tower effluent parameters, particularly drift, in the upper regions of the cooling tower plenum;

2. selection of a horizontal measurement plane within which effluent parameters will be acquired during the Seasonal Tests;

3. selection of a point within the horizontal plane at which the effluent parameters will be monitored during the Continuous Monitoring phase.

The following parameters:

1. drift droplet size distribution and number density,

2. sodium and magnesium mass flux,

3. air updraft velocity,

4. wet and dry bulb air temperature,

were recorded point by point along traverses of two orthogonal diameters lying in horizontal planes in and above the throat of the tower. The two planes and measuring diameters as shown in Figure 3-6 are:

Plane A - A horizontal plane through the throat (minimum cross-section) of the tower.

Plane B - A horizontal plane parallel to Plane A but as near the top of the tower as practicable (40-45 feet from the rim).

Plane B was located as high (or as close to the exit plane) as safely allowed by the cable rigging. No traverses were conducted for planes located below the cooling tower throat.

Description of Measurement Traverse Procedures

Point-By-Point Traverse (P-P) - These P-P traverses were designed to determine non-uniformity of the measured parameters across the effluent flow, and data at each point was taken in a manner designed to assure that any such non-uniformities were revealed. Measurements in

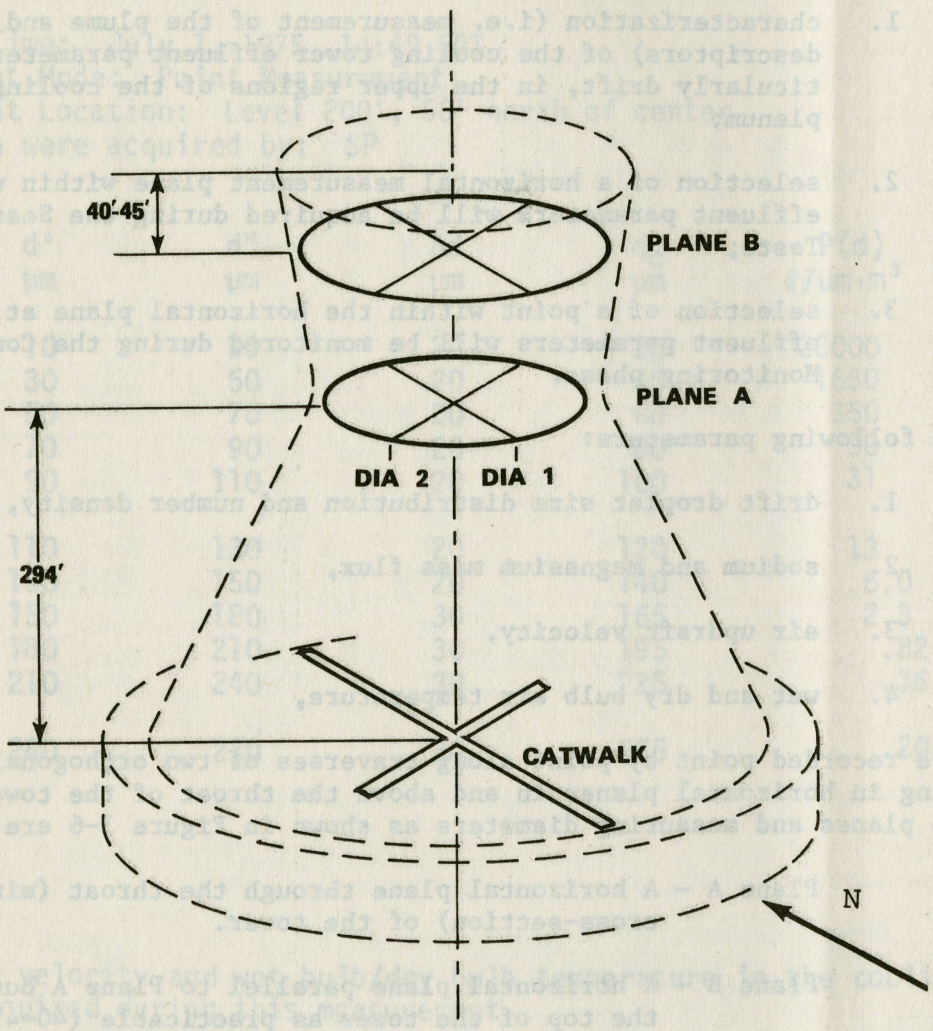


Fig. 3-6
(Reproduced from PPSP-CPCTP-3)

MEASUREMENT PLANES AND DIAMETERS FOR INITIAL CHARACTERIZATION CHALK POINT COOLING TOWER

this type of traverse were to be made for equal times at a number of points equally spaced across the diameter. The particular points along the diameter of traverse were chosen so that a change of approximately ±20% of the maximum time-mean updraft velocity could be resolved.

The P-P traverses proposed for the Initial Characterization Tests are given in Table 3-25. P_1 traverses in which drop size distribution is measured by PILLS required the longest sampling time at each point; in general, the time-determining element is the frequency of occurrence of large salt drift droplets (in the 300μ to 500μ size intervals). These traverses were very time consuming and were conducted during periods of predicted slow weather change.

Equal Area Traverse (EAT) - For most of the studies dealing with the external behavior of the cooling tower emission, a characterization of the plume as a whole is more useful. Drift parameters were also measured in both Planes A and B using an Equal Area Traverse (EAT). In this technique the circular plane area under study was divided into approximately 10 to 15 annular rings of equal area. Each annular ring was sampled at a point midway between its inner and outer diameter. As sampling progressed along cooling tower diameter #1 or #2, equal sampling times were used at each of the sampling points thus determined, and the integrated value of the parameter at all sample points was recorded. This type of traverse is appropriate for use with drop size and salt mass measurements and the statistical properties were determined by the integrated values. Therefore, relatively short sampling times at each point were possible. This type of traverse is not useful for continuous variables; e.g., temperature, velocity. Table 3-26 presents the EAT's to be used in initial characterization.

Use of the Data Sets - Collectively, this data characterize the emission parameters in the upper regions of the cooling tower. The same data base also enables the selection of a measurement plane for the seasonal intensive tests, and (according to the original plan) a measurement point for the continuous test phase. The data obtained were not sufficiently consistent to allow the selection of a "representative point" for continuous monitoring.

Table 3-25
(Reproduced from PPSP-CPCTP-3)
Point-Point Traverses to be Conducted in Initial Characterization

Type	Measured Parameter	Method	Sample Time	Total Time/Traverse[1]
P_I[8]	Drop Size Distrib. P(d)[2] Na and Mg Flux χ[5] Air Temp & Vel $T_W T_D, V$[7]	PILLS[3], SP[4] IK[6] See Note 7	1-2 hrs (8 pts)	12-20 hrs
P_{II}	Air Temp & Vel $T_W T_D, V$[7]	See Note 7	5 min (15 pts)	2-3 hrs

[1]The traverse times given here are the maximum as estimated by ESC. It is expected that tests subsequent to the first will require fewer points and hence less time.

[2]P(d) = Droplet Size Distribution and Number Density

[3]PILLS = Particulate Instrumentation by Laser Light Scattering

[4]SP = Sensitive Paper

[5] χ = Sodium and Magnesium mass flux, $\mu gm^{-2}s^{-1}$

[6]IK = Heated Glass Bead Isokinetic Sampler

[7]$T_W T_D, V$= Dry Bulb Air Temp, Wet Bulb Air Temp, Updraft (or Downdraft) Air Velocity, respectively. The instrumentation is described in the instrumentation sheets of Chapter 4. These quantities and their 15 minute standard deviations σ_{T_W}, σ_{T_D}, σ_V are recorded as averages over 15 minute time intervals.

[8]See Footnote 1, page 3-5, for description of traverse.

Table 3-26
(Reproduced from PPSP-CPCTP-3)
Equal Area Traverses to be Conducted in Initial Characterization

Type	Measured Parameter		Method	Sample Time/Pt	Total Time/Traverse[1]
E_I	Drop Size Distr.	P(d)[2]	PILLS[3]	1 hr (8 pts)	8-10 hrs
	Na and Mg Mass Flux	χ[5]	IK[6]		
E_{II}[7,8]	Drop Size Distr.	P(d)	SP[4]	15 min	2-4 hrs

[1]It is anticipated that fewer points per traverse will be required in traverses subsequent to the first. It is desired to obtain a representative drop size distribution in approximately two hours, but this possibility must be investigated through analysis of the first data sets.

[2]P(d) = Drop Size Distribution and Number Density

[3]PILLS = Particulate Instrumentation by Laser Light Scattering

[4]SP = Sensitive Paper

[5]χ = Sodium and Magnesium Mass Flux, $\mu gm^{-2}s^{-1}$

[6]IK = Heated Glass Bead Isokinetic Sampler

[7]Requires additional field tests to establish feasibility of using SP in EAT mode. If this proves to be not feasible, point-point mode will be used, and an attempt will be made to relate the data to the equal-area scheme.

[8]Normally E_I and E_{II} traverses will be conducted concurrently. E_{II} is defined as a separable traverse type for purposes of identification in the event traverses without PILLS and IK are occasionally desired.

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Selection of a Representative Plane for Seasonal Intensive Tests

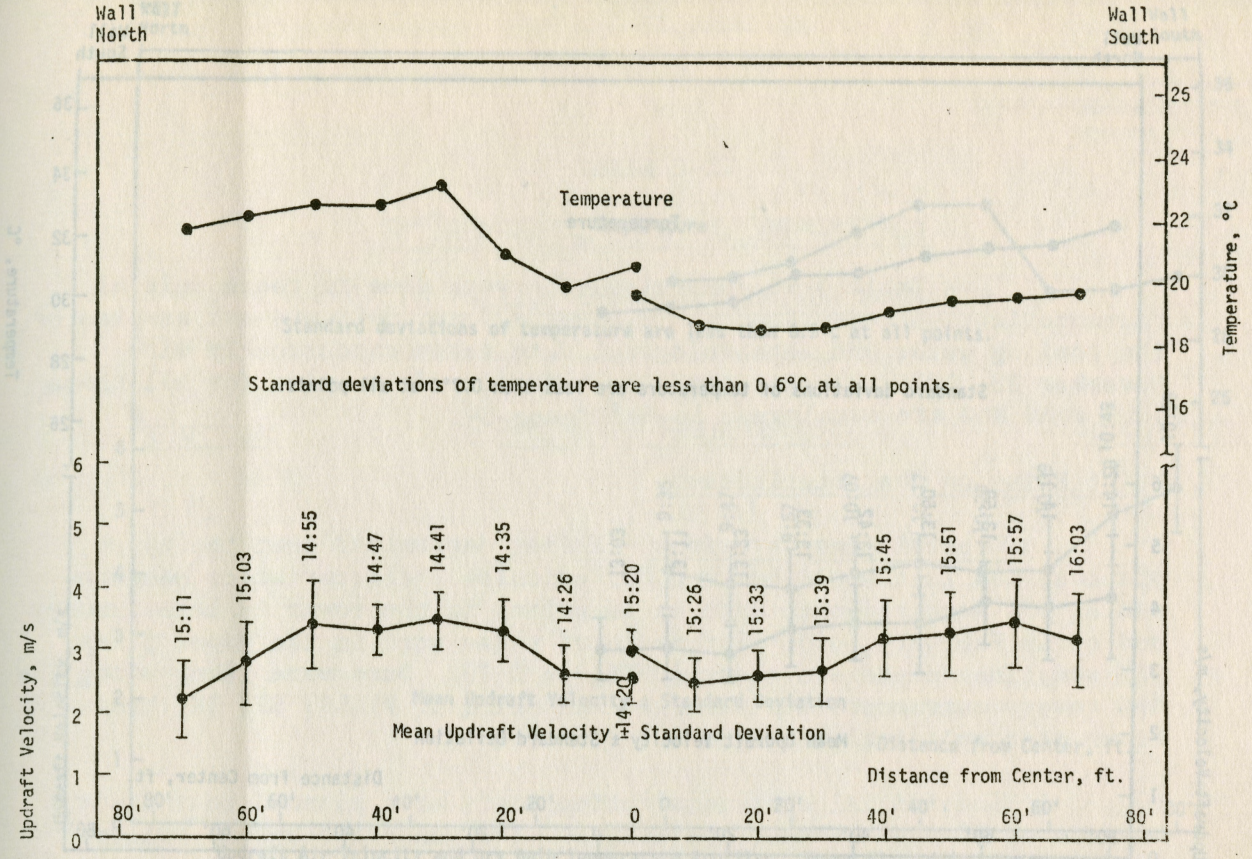
General Considerations - In the selection of a representative plane it was desired that the disturbance of the profiles of updraft velocity, variation in updraft velocity, and temperature due to wind effects at the rim of the tower be small. On the other hand, it was also desired to use a plane as close to the rim as possible so that the measurements would be representative of effluent characteristics. These criteria are conflicting.

In the selection of a representative plane, the diameter profiles of the time-mean updraft velocity, the standard deviation of the updraft velocity, and the air temperature taken as described earlier were studied for each plane. The more uniform the profiles of the time-mean velocity, the stronger was our expectation of a drift droplet size distribution that is invariant along the diameter.

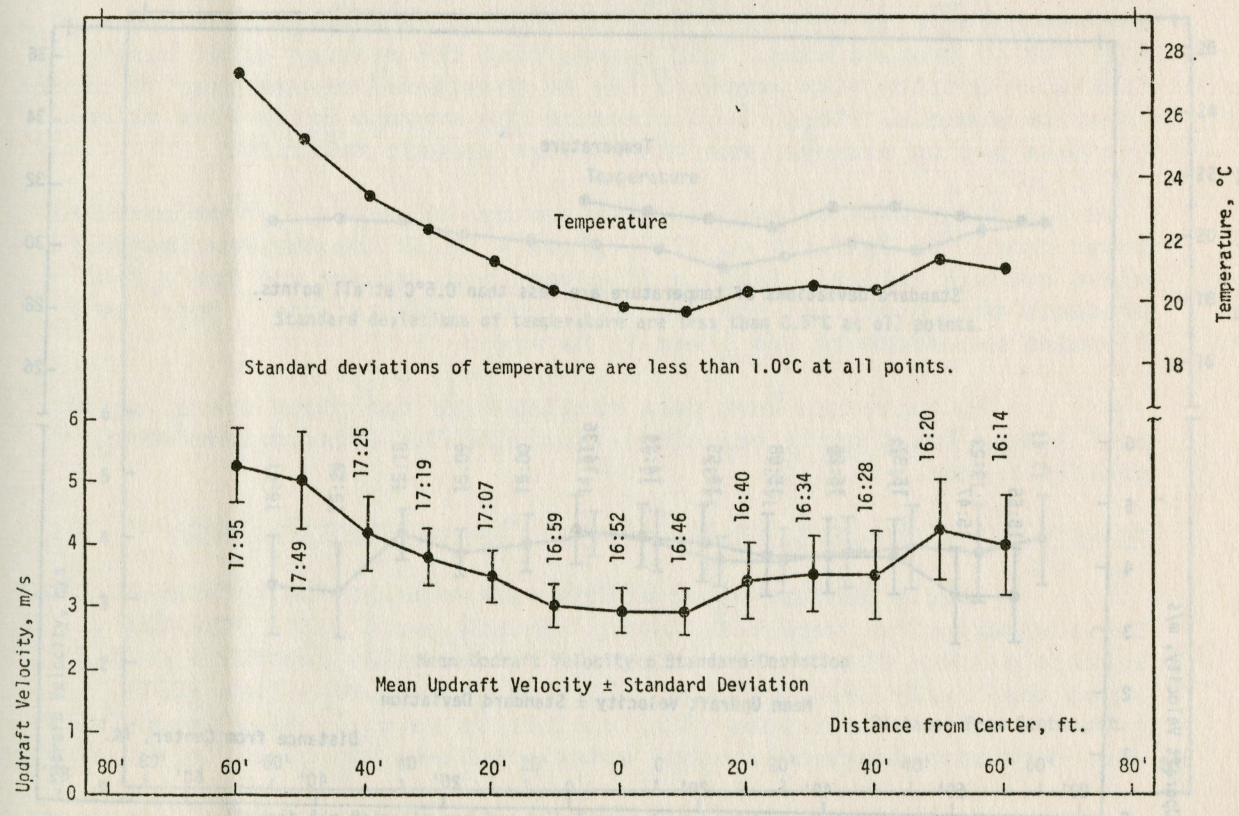
The purpose for which the representative plane is required was also an important consideration. In the Seasonal Intensive Test, it was necessary to obtain a rather rapid emission characterization. The more uniform the profiles, including drift droplet size characterizations, the smaller the number of points required to accurately measure the emission of the cooling tower. Thus, air updraft velocity and temperature profiles were important for the plane selection because they were obtainable within a time frame of about one hour and were, therefore, relatively free of effects of changing tower operation and meteorological conditions.

A representative plane (Plane B) was selected on the basis of minimum velocity profile disturbance due to external factors. It was necessary, however, that the drift data be reviewed carefully to assure that the drift values obtained were truly representative of the drift emission. Inspection of data throughout the characterization test was required to resolve this problem. The representative plane was used for the measurement of all tower effluent parameters in all seasonal intensive tests.

Data for the Selection of a Representative Plane - During the period September 27, 1975 through January 27, 1976, ESC conducted 25 traverses of the P_{II} type for the purpose of selecting a representative plane for subsequent source term measurement. It was expected that rim effects would cause much larger vertical velocity fluctuations at the upper plane, 354 foot level, than at the throat level, 294 foot. It was desired to select a plane as high in the tower as possible so that the measurements would represent exit characteristics. Figures 3-7 through 3-9 show that the velocity fluctuations in upper and lower planes are not significantly different. ESC, therefore, selected the upper plane for the conduct of its subsequent emission characterizations.

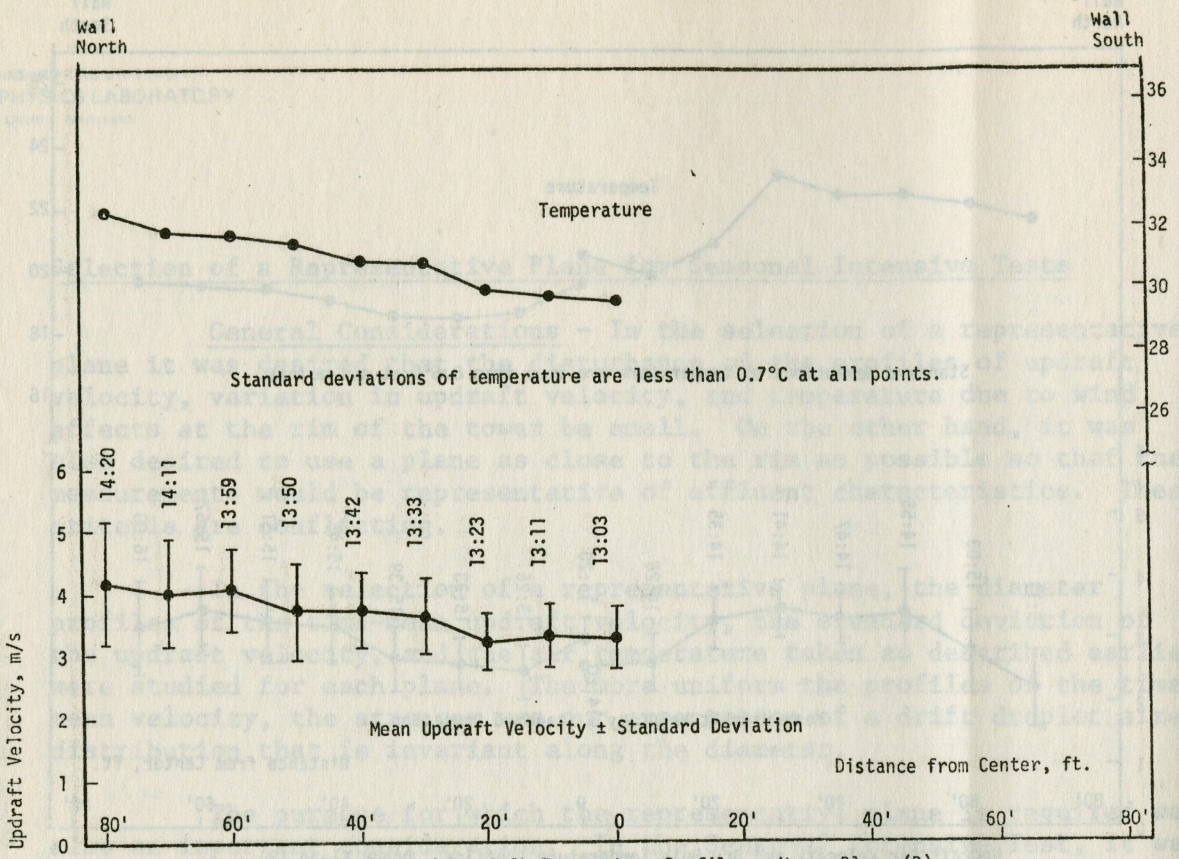


Updraft Air Velocity and Dry Bulb Temperature Profiles. Upper Plane (B)
Chalk Point Unit #3 Cooling Tower, November 28, 1975. 14:20 - 16:08 EST
Data points are averages over a 5-minute period with starting times indicated.

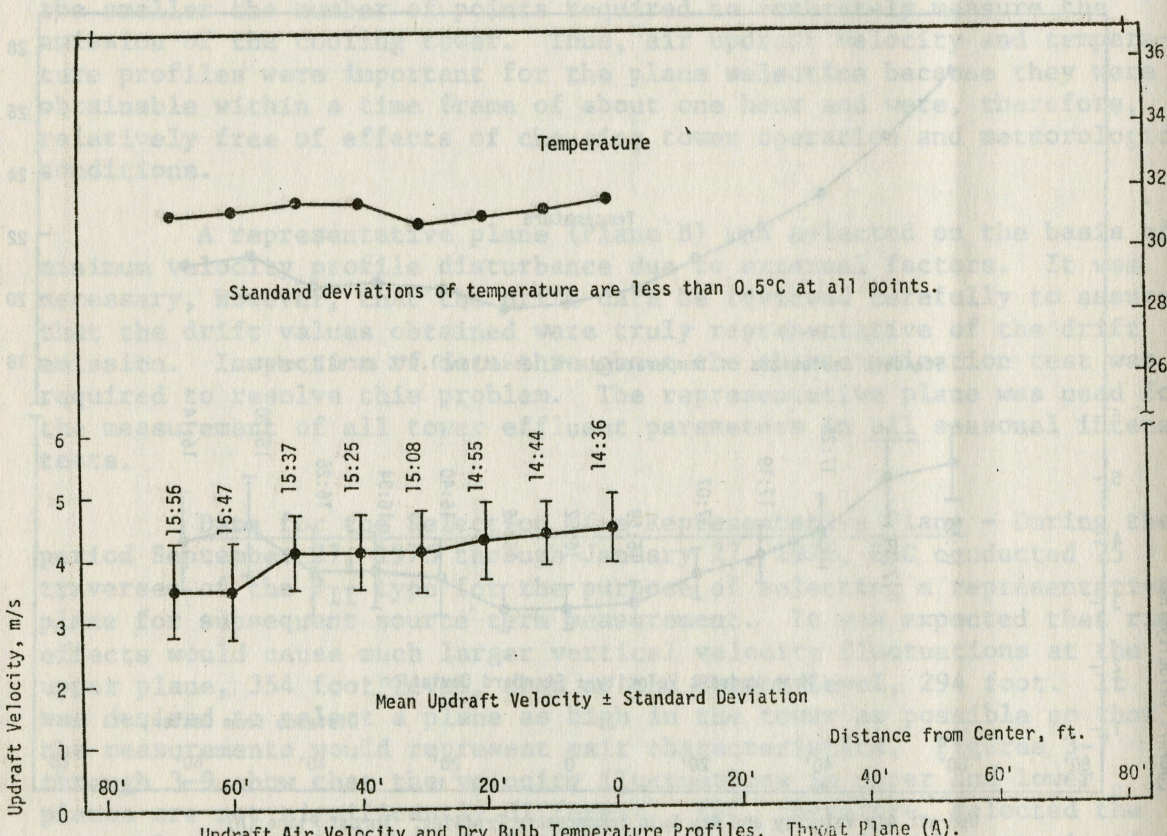


Updraft Air Velocity and Dry Bulb Temperature Profiles. Throat Plane (A)
Chalk Point Unit #3 Cooling Tower. November 28, 1975. 16:14 - 18:00 EST
Data Points are averages over a 5-minute period with starting times indicated.

Figure 3-7. Sample #1, Determination of a Representative Plane. (Reproduced from PPSP-CPCTP-9, Vol III)

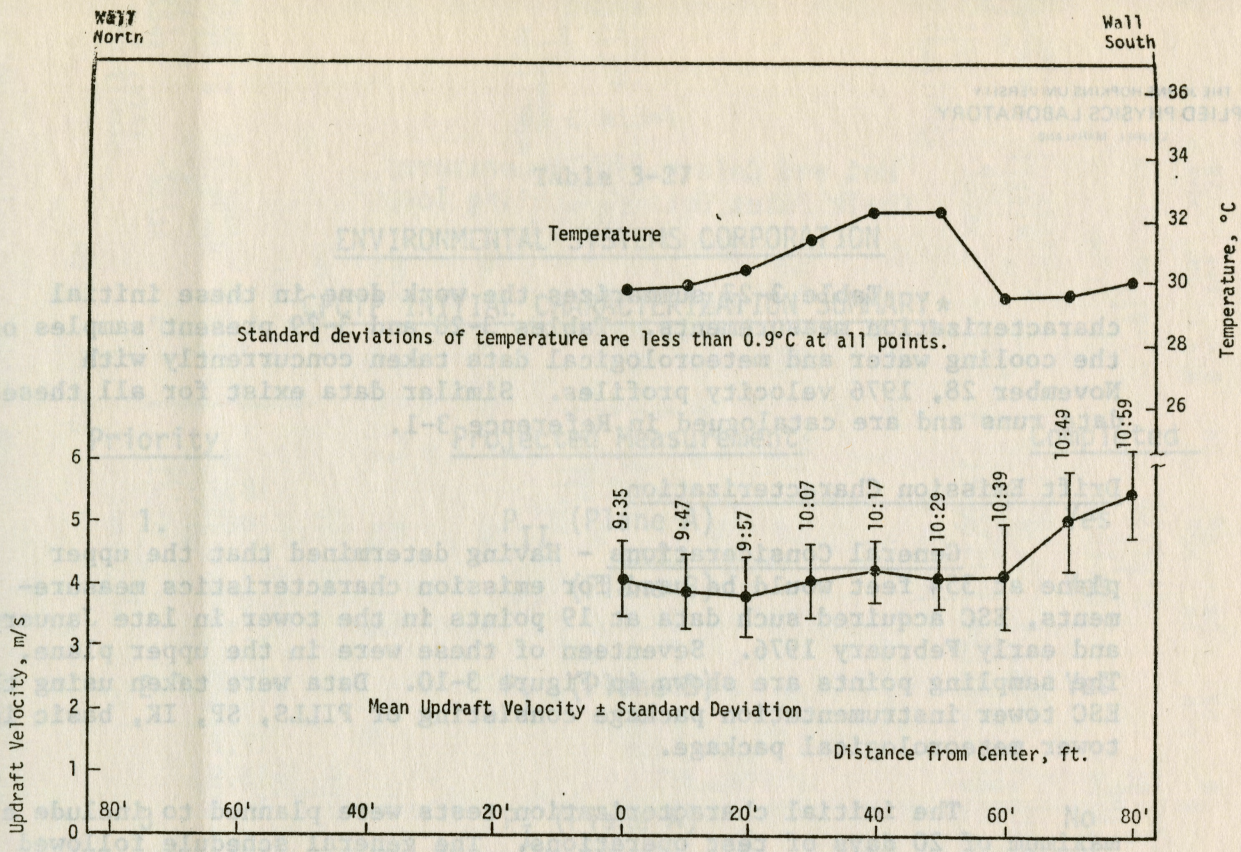


Updraft Air Velocity and Dry Bulb Temperature Profiles. Upper Plane (B).
Chalk Point Unit #3 Cooling Tower. January 26, 1976. 13:03 - 14:25 EST.
Data Points are averages over a 5-minute period with starting times indicated.

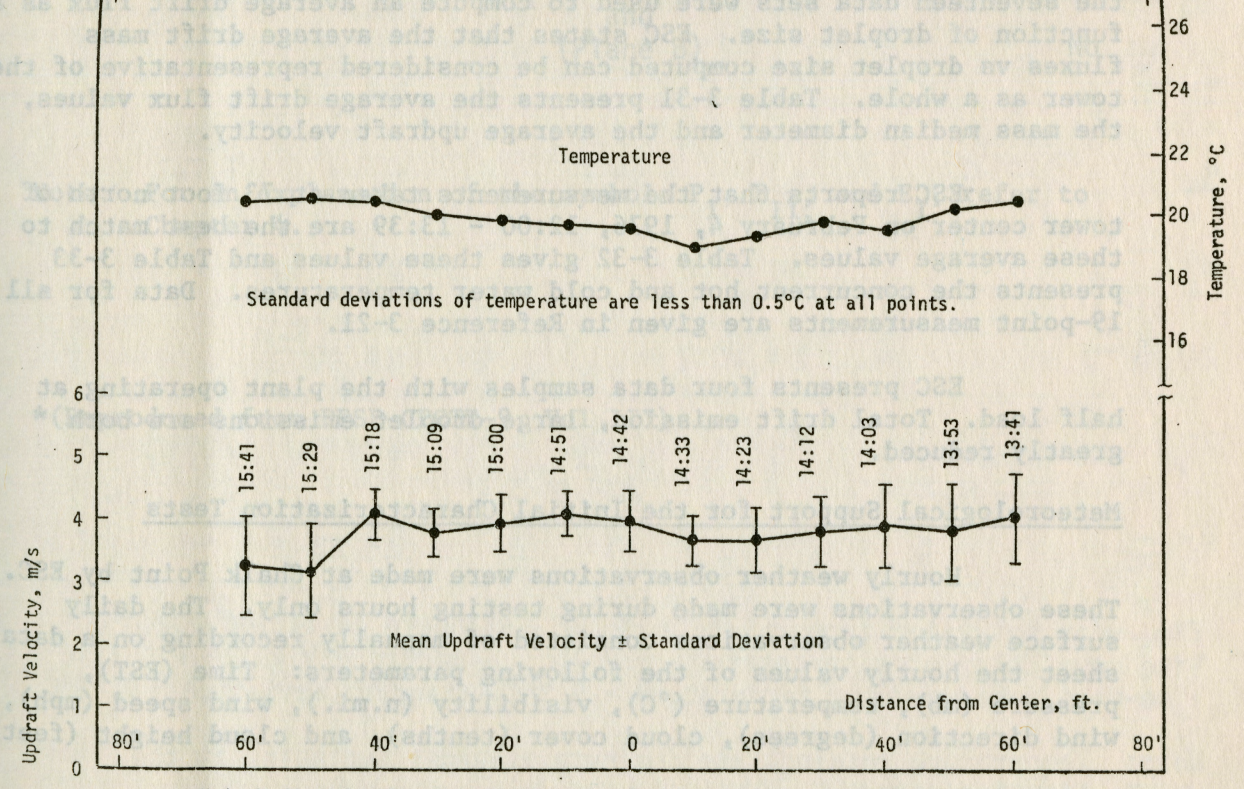


Updraft Air Velocity and Dry Bulb Temperature Profiles. Throat Plane (A).
Chalk Point Unit #3 Cooling Tower. January 26, 1976. 14:36 - 16:01 EST.
Data Points are averages over a 5-minute period with starting times indicated.

Figure 3-8. Sample #2, Determination of a Representative Plane. (Reproduced from PPSP-CPCTP-9, Vol III)



Updraft Air Velocity and Dry Bulb Temperature Profiles. Upper Plane (B).
Chalk Point Unit #3 Cooling Tower. January 27, 1976. 9:35 - 11:04 EST
Data Points are averages over a 5-minute period with starting times indicated.



Updraft Air Velocity and Dry Bulb Temperature Profiles. Throat Plane (A).
Chalk Point Unit #3 Cooling Tower. January 27, 1976. 13:41 - 15:46 EST.
Data Points are averages over a 5-minute period with starting times indicated.

Figure 3-9. Sample #3, Determination of a Representative Plane. (Reproduced from PPSP-CPCTP-9, Vol III)

Table 3-27 summarizes the work done in these initial characterization measurements. Tables 3-28 and 3-29 present samples of the cooling water and meteorological data taken concurrently with November 28, 1976 velocity profiles. Similar data exist for all these data runs and are catalogued in Reference 3-1.

Drift Emission Characterization

General Considerations - Having determined that the upper plane at 354 feet would be used for emission characteristics measurements, ESC acquired such data at 19 points in the tower in late January and early February 1976. Seventeen of these were in the upper plane. The sampling points are shown in Figure 3-10. Data were taken using the ESC tower instrumentation package consisting of PILLS, SP, IK, basic in tower meteorological package.

The initial characterization tests were planned to include a maximum of 20 days of test operations. The general schedule followed appears as Table 3-30.

Data for the Definition of Drift Emission - Data from ten of the seventeen data sets were used to compute an average drift flux as a function of droplet size. ESC states that the average drift mass fluxes vs droplet size computed can be considered representative of the tower as a whole. Table 3-31 presents the average drift flux values, the mass median diameter and the average updraft velocity.

ESC reports that the measurements taken at 73 foot north of tower center on February 4, 1976, 12:00 - 13:39 are the best match to these average values. Table 3-32 gives these values and Table 3-33 presents the concurrent hot and cold water temperatures. Data for all 19-point measurements are given in Reference 3-21.

ESC presents four data samples with the plant operating at half load. Total drift emission, large droplet emissions are both greatly reduced.

Meteorological Support for the Initial Characterization Tests

Hourly weather observations were made at Chalk Point by ESC. These observations were made during testing hours only. The daily surface weather observations consisted of manually recording on a data sheet the hourly values of the following parameters: Time (EST), pressure (mb), temperature (°C), visibility (n.mi.), wind speed (mph), wind direction (degrees), cloud cover (tenths), and cloud height (feet).

There were no special meteorological requirements or meteorological data requirements associated with the Stack #3 emission characterization.

Table 3-27

ENVIRONMENTAL SYSTEMS CORPORATION

CPCTP INITIAL CHARACTERIZATION SUMMARY*

Priority	Projected Measurement	Completed
1.	P_{II} (Plane A)	Yes
	and	
	(Plane B)	Yes
2	P_I (Plane B)	Yes
3	P_I (Plane A)	No
4	E_I (Plane A)	No
	and	
	(Plane B)	No

Note: For an explanation of the symbols P_I, P_{II}; and E_I, refer to Chapter 4.

*(Reproduced from PPSP-CPCTP-9, Vol III)

Table 3-28

Hot and Cold Water Temperatures
Chalk Point Unit #3 Cooling Tower
November 28, 1975

Time EST	Hot Water °C	Cold Water °C
1420	29.5	18.4
1426	28.0	18.4
1435	27.6	18.4
1441	27.3	18.0
1447	26.2	17.9
1455	25.6	17.7
1503	24.8	17.6
1511	23.9	17.2
1520	23.5	17.2
1526	23.6	16.9
1533	23.6	16.6
1539	23.7	16.6
1545	23.3	16.6
1551	23.2	16.4
1557	23.6	16.6
1603	24.6	16.7

Time-mean hot water temperature = 25.1°C , standard deviation = 2.0°C
Time mean cold water temperature = 17.3°C , standard deviation = 0.73°C
Time-mean make-up water temperature = 9.3°C, standard deviation = 0.23°C

Note: Temperature readings are 5-minute averages beginning at the time indicated.

(Reproduced from PPSP-CPCTP-9, Vol III)

Table 3-29. Meteorological Data Sample (Initial Characterization)
(Reproduced from PPSP-CPCTP-9, Vol III)

CHALK POINT DATA REDUCTION DAYS 331-338 DATE 121375 PAGE 29

AVERAGE TIME - DAY 332 HOUR 14 MINUTE 30 OBSERVATIONS 180 INTERVAL 55 RECORD 56

	WIND(10) VELOC.	WIND(10) DIRCT.	WIND(50) VELOC.	WIND(50) DIRCT.	WIND(100) (HORZ.) VELOC.	WIND(100) (HORZ.) DIRCT.	WIND(100) (VERT.) VELOC.	WIND(100) (VERT.) DIRCT.
OBS.	180	180	180	180	180	180	180	180
MEAN	3.050	346.200	4.170	329.700	4.480	337.600	-.060	-.700
SIGMA	1.383582	47.748612	1.194069	35.823037	1.032037	13.837991	.645678	8.900000
VECT SIGMA	.006697	.006067	.004414	.002995	.002344	.002284	-.104150	-.026822

	DEW PT.(10)	DEW PT.(100)	GRAD(10)	GRAD(50)	TEMP(100)	HEAT FLUX
OBS.	71	180	180	180	180	180
MEAN	4.440	-2.760	-.010	-.005	8.210	.073400
SIGMA	8.586379	1.029854	.320468	.295087	.233452	

WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	16%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	26%	57%

AVERAGE TIME - DAY 332 HOUR 15 MINUTE 0 OBSERVATIONS 180 INTERVAL 56 RECORD 57

	WIND(10) VELOC.	WIND(10) DIRCT.	WIND(50) VELOC.	WIND(50) DIRCT.	WIND(100) (HORZ.) VELOC.	WIND(100) (HORZ.) DIRCT.	WIND(100) (VERT.) VELOC.	WIND(100) (VERT.) DIRCT.
OBS.	180	180	180	180	180	180	180	180
MEAN	3.100	333.300	4.420	323.000	3.780	323.700	-.100	-1.500
SIGMA	.887919	40.193656	.878521	16.500606	.737970	12.462744	.514879	8.184131
VECT SIGMA	.005357	.003413	.002262	.001962	.001964	.002101	-.050050	-.011951

	DEW PT.(10)	DEW PT.(100)	GRAD(10)	GRAD(50)	TEMP(100)	HEAT FLUX
OBS.	68	180	180	180	180	180
MEAN	2.820	-2.900	-.007	-.005	8.370	.030800
SIGMA	2.081226	1.266965	.520384	.337491	.189737	

WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	53%	36%

AVERAGE TIME - DAY 332 HOUR- 15 MINUIE 30 OBSERVATIONS 180 INTERVAL 57 RECORD 58

	WIND(10) VELOC.	WIND(10) DIRCT.	WIND(50) VELOC.	WIND(50) DIRCT.	WIND(100) (HORZ.) VELOC.	WIND(100) (HORZ.) DIRCT.	WIND(100) (VERT.) VELOC.	WIND(100) (VERT.) DIRCT.
OBS.	180	180	180	180	180	180	180	180
MEAN	3.490	321.800	4.530	310.500	4.220	309.700	-.020	-.200
SIGMA	.855804	17.902793	.990959	11.599569	.816352	10.420173	.533104	8.448666
VECT SIGMA	.002904	.001893	.002261	.001747	.001941	.001748	-.257682	-.067455

	DEW PT.(10)	DEW PT.(100)	GRAD(10)	GRAD(50)	TEMP(100)	HEAT FLUX
OBS.	47	180	179	180	180	180
MEAN	3.230	-2.310	-.006	-.004	8.360	.019100
SIGMA	5.815316	2.280504	.252784	.328938	.183303	

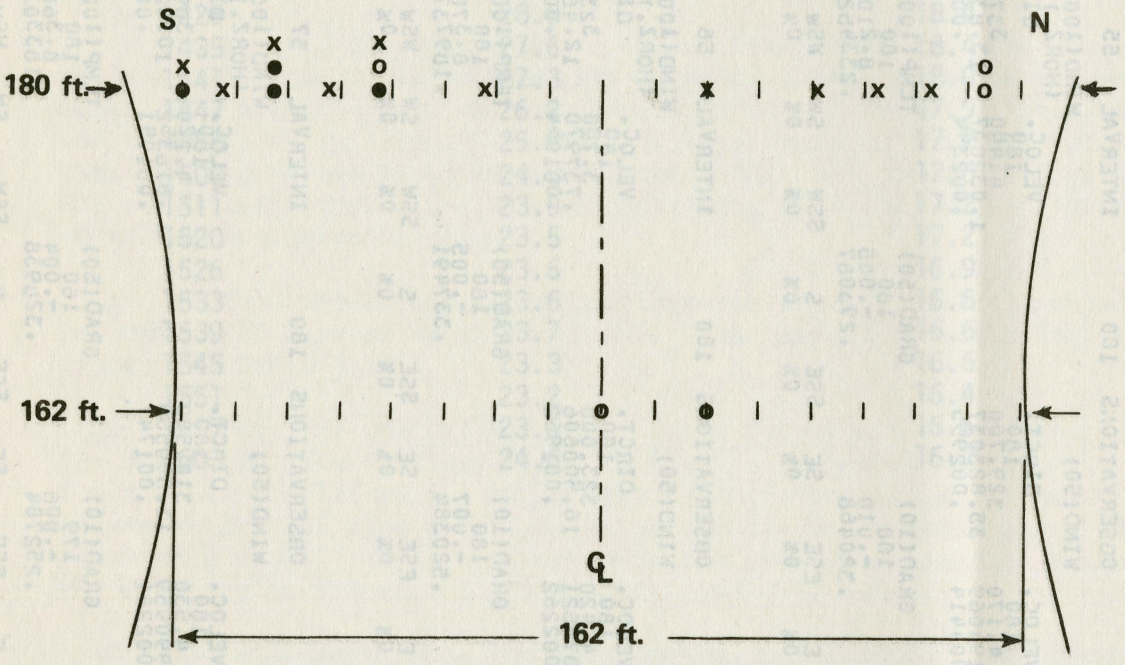
WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	27%	64%	7%

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Fig. 3-10

Data Acquisition Points for Mass Flux vs. Particle Size

INITIAL CHARACTERIZATION



x These points used in obtaining an average distribution

• These points taken at approximately 50% plant load and were not used in the 10 pt. averages.

o Point not used for other reasons.

Upper plane at 354'

Lower plane at 294'

Table 3-30

Desired Scope of Initial Characterization Tests

(Reproduced from PPSP-CPCTP-3)

Schedule for Days 1 through 10. All measurements will be taken on Diameter 1, but on the planes indicated and at points to be preselected.

Day	Event
1	Type P_{II} traverse on Planes A and B (4-6 hours)
2-3	Type P_I traverse on Plane B (8-10 hours)
4	Type P_I traverse on Plane A
	NOTE: This test is predicated on the idea that the traverses can be done adequately with fewer points than were used on Day 2.
5-8	Type E_I traverses on Planes A and B. (Actually combined E_I and E_{II}).
9-10	Repeat Type P_I and P_{II} traverses on plane selected for further testing.

Schedule for Days 11 through 20. Repeat all tests for Days 1 through 10 on Diameter 2. This requires rerigging the cables in the cooling tower.

Table 3-31

CHALK POINT UNIT #3 COOLING TOWER
AVERAGE DRIFT FLUX AS A FUNCTION
OF DROPLET SIZE

(Reproduced from PPSP-CPCTP-9, Vol III, p.23)

I	d' μm	d" μm	Δd μm	d_c μm	ΔF $\mu g/m^2 s$	ΔF/F %
1	10	30	20	20	2794	10.2
2	30	50	20	40	2437	8.9
3	50	70	20	60	1960	7.2
4	70	90	20	80	1869	6.8
5	90	110	20	100	1729	6.3
6	110	130	20	120	1756	6.4
7	130	150	20	140	1713	6.3
8	150	180	30	165	2419	8.9
9	180	210	30	195	2173	8.0
10	210	240	30	225	1889	6.9
11	240	270	30	255	1422	5.2
12	270	300	30	285	978	3.6
13	300	350	50	325	1022	3.7
14	350	400	50	375	726	2.7
15	400	450	50	425	535	2.0
16	450	500	50	475	416	1.5
17	500	600	100	550	618	2.3
18	600	700	100	650	473	1.7
19	700	800	100	750	214	0.8
20	800	900	100	850	105	0.4
21	900	1000	100	950	29.1	0.1
22	1000	1100	100	1050	10.7	0.04
23	1100	1200	100	1150	1.18	0.004
				$F_{avg} = \Sigma\Delta F = 27{,}300$		99.9*

Mass Median Diameter = 143μm

Average updraft velocity = 4.62 m/sec.

* This column does not add up to 100% due to rounding.

These values represent an average from the following measurement points in Appendix II: 2/2/76, 80'S; 2/6/76, 73'S; 2/2/76, 64'S; 2/5/76, 54'S; 2/3/76, 14:51 EST, 42'S; 2/5/76, 24'S; 2/4/76, 24'N; 2/5/76, 42'N; 2/4/76, 54'N; 2/4/76, 64'N.

Table 3-32. Measurements in the Unit #3 Natural Draft Cooling Tower.

(Reproduced from PPSP-CPCTP-9, Vol III)

Drift Mass Flux as a Function of Droplet Size

Date and Time: February 4, 1976, 1209 - 1339 EST
Measurement Mode: Point Measurement
Measurement Location: Level 354', 73' north of center
These data were acquired by: PILLS and SP

I	d' μm	d" μm	Δd μm	d_c μm	ΔF μg/m²s	ΔF/F %
1	10	30	20	20	3770	13.4
2	30	50	20	40	2690	9.6
3	50	70	20	60	1890	6.7
4	70	90	20	80	1580	5.6
5	90	110	20	100	1480	5.3
6	110	130	20	120	1670	5.9
7	130	150	20	140	1810	6.4
8	150	180	30	165	2800	9.9
9	180	210	30	195	2680	9.5
10	210	240	30	225	2470	8.8
11	240	270	30	255	1840	6.5
12	270	300	30	285	1050	3.7
13	300	350	50	325	858	3.1
14	350	400	50	375	444	1.6
15	400	450	50	425	269	1.0
16	450	500	50	475	186	0.7
17	500	600	100	550	283	1.0
18	600	700	100	650	273	1.0
19	700	800	100	750	136	0.5
					F = ΣΔF ≈ 28,200	100.2*

Mass Median Diameter: 141 μm

* This column does not add up to 100% due to rounding.

Mineral Mass Fluxes[1]

Date and Time, Measurement Mode and Location Same as A. 1.
These Data were Acquired by: Isokinetic Sampling System

Sodium flux: 65.6 μg/m²·s
Magnesium flux: 8.46 μg/m²·s

Basin Water Concentrations:

Sodium concentration: 855 mg/liter
Magnesium concentration: 100 mg/liter

Selected Cooling Tower Water and Air Circuit Parameters

The following data are averaged over the approximate measurement time period:

Updraft air velocity:	4.7 m/s,	Standard deviation:	0.67 m/s
Wet bulb temperature:	27.0 °C ,	" " :	1.20°C
Dry bulb temperature:	26.7 °C ,	" " :	1.04°C
Hot water temperature:	36.7 °C ,	" " :	0.83°C
Cold water temperature:	22.0 °C ,	" " :	0.36°C
Make-up water temperature:	7.9 °C ,	" " :	0.25°C
Circulating water flow rate:	984.1 m³/min or 260,000 gpm (See Footnote[2])		
Make-up flow rate:	See Footnote [3]		
Blowdown flow rate:	See Footnote [3]		

[1] As measured by IK only. Backup filter collections were in the average less than 2.5% of the IK collections and are neglected.

[2] Design value. Sensor not installed.

[3] Sensors not operational.

Table 3-33. Hot and Cold Water Temperatures - Chalk Point Unit #3 Cooling Tower, February 4, 1976.

(Reproduced from PPSP-CPCTP-9, Vol III)

Time EST	Hot Water °C	Cold Water °C
1209	35.4	21.5
1219	34.8	21.7
1229	34.7	21.7
1239	36.1	21.9
1249	35.3	22.0
1259	36.1	22.2
1309	35.0	22.4
1319	36.3	22.4
1329	37.2	22.5

Time-mean hot water temperature = 35.7°C , standard deviation = 0.83°C
Time-mean cold water temperature = 22.0°C , standard deviation = 0.36°C
Time-mean make-up water temperature = 7.9°C , standard deviation = 0.25°C

Note: Temperature readings are 10-minute averages beginning at the time indicated.

Plant Operating Data in Support of Initial Characterization Test

In support of the Initial Characterization Tests, several plant operating parameters were logged. The plant generating load and circulating water flow rate were recorded by PEPCO. ESC was responsible for measurement of the condenser inlet and outlet water temperatures, blowdown rate, makeup rate, and basin mineral concentration.

It was required that the general flow parameters of the scrubber system and the salt concentration in the circulating scrubber water be measured concurrently during the Stack #3 emission tests.

CONTINUOUS MONITORING

The continuous monitoring phase of the CPCTP began in July 1972 when the University of Maryland began collecting background data at Chalk Point and is projected to be completed two years after Unit #4 comes on line. Environmental Systems Corporation began its continuous monitoring when Unit #3 came into service in May 1975. Their tests encompassed one year.

The complete continuous monitoring program consisted of:

a. Characterization of the actual long-range impact on soils, agricultural crops and botanical species in the vicinity of Chalk Point. (University of Maryland)

b. Collection of ambient meteorological data from the three levels of a 300-foot meteorological tower and rain gauges in the vicinity of the tower. (ESC)

c. Characterization of the ambient air concentration of particulates by means of the airborne particle samplers, dustfall buckets, sulfation plates and sensitive papers and the characterization of the cooling tower effluent. (ESC)

d. Measurement of circulating water parameters, mineral contents of the basin water, and gross MWh of operation of the Unit #3 cooling tower. (ESC and PEPCO)

Continuous monitoring also included measurement of drift droplet size and number density as measured by the PILLS instrument at various points on the representative plane along with the other tower effluent parameters previously explained. Sensitive Paper (SP) and Isokinetic (IK) were not included. During the continuous monitoring phase of the cooling tower operations, ambient meteorology was provided by the on-site meteorological tower and hourly weather observations.

Selection of the Measurement Point for Continuous Monitoring

Using the data taken above, it was planned to select a measurement point within the representative plane as the point at which the instrument package would be suspended during the Continuous Monitoring Phase. The more uniform the distribution of effluent parameters is in the representative plane, the less critical is the exact location of the point of measurment and the more accurate the determination of the cooling tower emission. Such a "representative point" was not found; the variation in drift parameters being highly variable with respect to both the position of measurement and the time of measurement.

SEASONAL INTENSIVE TESTING

General Considerations

Seasonal intensive data acquisition periods were designed to obtain sets of simultaneous data on tower emission, non-reacting plume characteristics, and salt deposition at ground level. These data sets were intended to be self-consistent, and to provide the experimental basis for the development, test, and extension of salt drift models applicable to natural draft cooling towers. During this series of tests an attempt was also made to acquire data relating to chemical processes occurring in the regions of interaction between cooling tower plumes and fossil fuel stack emissions.

Source Emission Characterization for Intensive Tests

Since it was a major goal of the intensive test program to permit the validation of salt drift models, it was necessary to consider the possible salt emission contributions of the cooling tower, Stack #3 and Stacks #1 and #2. The program for test execution follows:

Cooling Tower Emission Characterization for Seasonal Test - During the seasonal tests, drift characterization was by Equal Area Traverses with the PILLS, SP, and IK drift measurement systems. These traverses characterized the drift emissions of the tower as a whole under varying seasonal conditions. These traverses were conducted on the selected representative plane (Plane B). Each E_1 and E_2 traverse required some 4 to 6 hours and bracketed the aircraft operating period (nominally 3 to 4 hours). Data were also collected for water circuit parameters, basin salinity and the generating load. The data are reported in References 3-26 and 3-33.

In addition, when plume rise and/or drift model validation tests were conducted, temperature, velocity, and humidity data were taken at each of the measurement stations of the EAT. With proper weighting, this allows the computation of velocity, temperature, virtual temperature, and vapor content of the plume at the cooling tower exit.

Stack #3 Emissions Characterization in Intensive Tests - At the PEPCO Chalk Point Power Station, the combustion gases from the boilers of Unit #3 are passed through a water spray particulate scrubber system before exiting through a 700-foot stack. The water used in the scrubber is taken from the Patuxent River and as such contains the same types of minerals as the circulating water in the Unit #3 cooling tower and at a relatively higher concentration.

Since even a rough estimate of the stack emission level was unknown, either by PEPCO or the scrubber supplier, an emissions test series was conducted in the Unit #3 stack to characterize the stack emissions to the extent required for the modeling of salt drift impact.

It should be noted that the intial characterization was done with the scrubber operating at "off design" conditions. The design pressure drop through the scrubber is approximately sixteen inches of water; however, due to equipment malfunction, it was operating at less than nine inches of water during the test period.

Meteorology in Support of the Seasonal Intensive Test Program

Meteorological support during the Seasonal Intensive Test phase, particularly during those tests designed to provide validation of plume rise or drift models, was much more extensive than that previously described for the initial characterization tests. The services arrangements and data requirements were as follows:

On-Site Hourly Surface Data and Local Observations - During all phases of the cooling tower testing, hourly weather observations were made at Chalk Point by ESC. The observations were made during the daily testing hours.

Meteorological Tower - The Chalk Point 100-meter meteorological tower with temperature and wind at three levels and dewpoint at two levels provided data identical to that used in the emission characterization tests described earlier.

Rawinsonde and Pibal Data for Seasonal Intensive Tests - These data were taken only for the tests in which model validation data were being taken. Rawinsonde support during the intensive tests had two objectives: to support ESC's tower and plume measurements, and to support MRI's aircraft plume measurements. Rawinsonde data were taken at least three times during the daily operations. When required, additional rawinsondes were conducted.

General Meteorology Records by Aircraft Operators - General meteorological data were recorded manually in the instrument operator's

log book. Specific meteorological conditions including pressure altitude, temperature profiles, humidity, and visibility were recorded on magnetic data tape from the aircraft instruments.

Airborne Monitoring Facility

A Cessna 205 aircraft was prepared for use in the airborne monitoring program. It was modified to carry instrumentation for plume measurements. This includes equipment for the measurement of temperature, humidity, drop size, and the presence of chemical reaction products.

Airborne Monitoring of Vapor, Drift, and Chemical Interaction Plumes

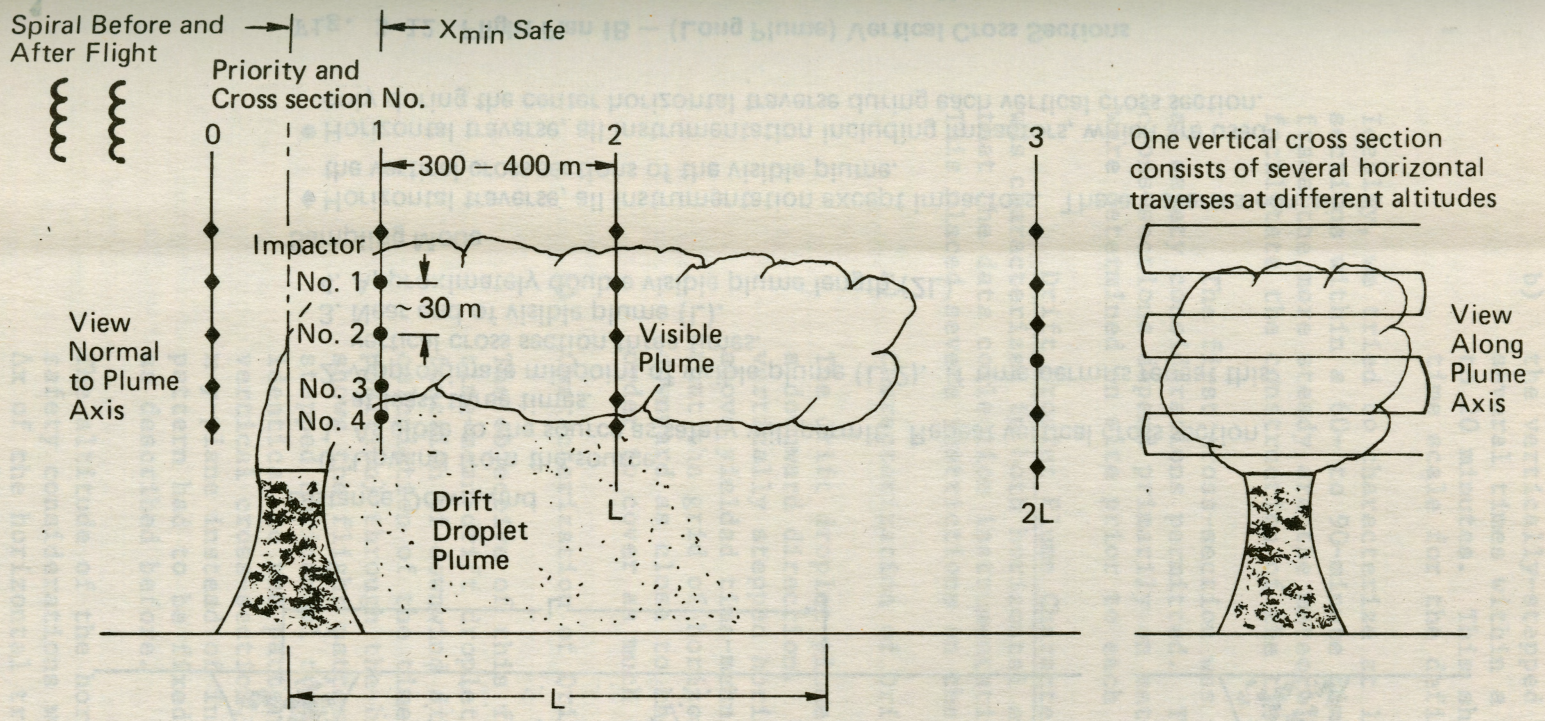
The primary objective of this airborne monitoring program was the collection of data in and under the visible vapor plume of the cooling tower for use in the validation of models. In addition, it was planned to conduct exploratory surveys for the presence of chemical interactions in the intersection volumes of fossil fuel stack plumes and the cooling tower plume.

Drift transport and vapor plume dispersion models require time-mean parameters as input. In order to obtain time-mean plume parameters for use in model validation by means of airborne monitoring the following flight plans were recommended.

The flight plans shown are different for vapor plume and drift droplet plume characterizations but can be, and usually are, combined into one flight plan.

Vapor Plume Characterization - The vapor plume can be sufficiently characterized by vertical time-mean cross sections at three (or more) downwind distances. The flight pattern in each vertical cross section consisted of vertically stepped horizontal traverses as shown in Figures 3-11 and 3-12. The actual number of horizontal traverses depended on the altitude steps Δz and the vertical extent of the plume. A Δz of 100 to 200 feet and a total of 5 or 6 horizontal traverses were usually adequate. The vapor plume changes shape and location continuously. Therefore, at a fixed downwind distance x_1, the geometry of the cross section and its location were different for each flight along the horizontal traverses. However, the time-mean vapor plume cross-sections and their locations in space could be determined if

a) the flight pattern, i.e., the vertically-stepped horizontal traverses, were fixed in space. In other words, even though the plume cross section changes and moves around at a downwind location x_1 the grid of horizontal traverses remains fixed in space.



0. Upwind from the source
1. As close to the source as safety will permit. Repeat vertical crossection at least three times.
2. Near end of visible plume (L). Repeat vertical crossection three times or more if time permits.
3. Approximately double visible plume length (2L). Attempt this vertical crossection only if time permits.

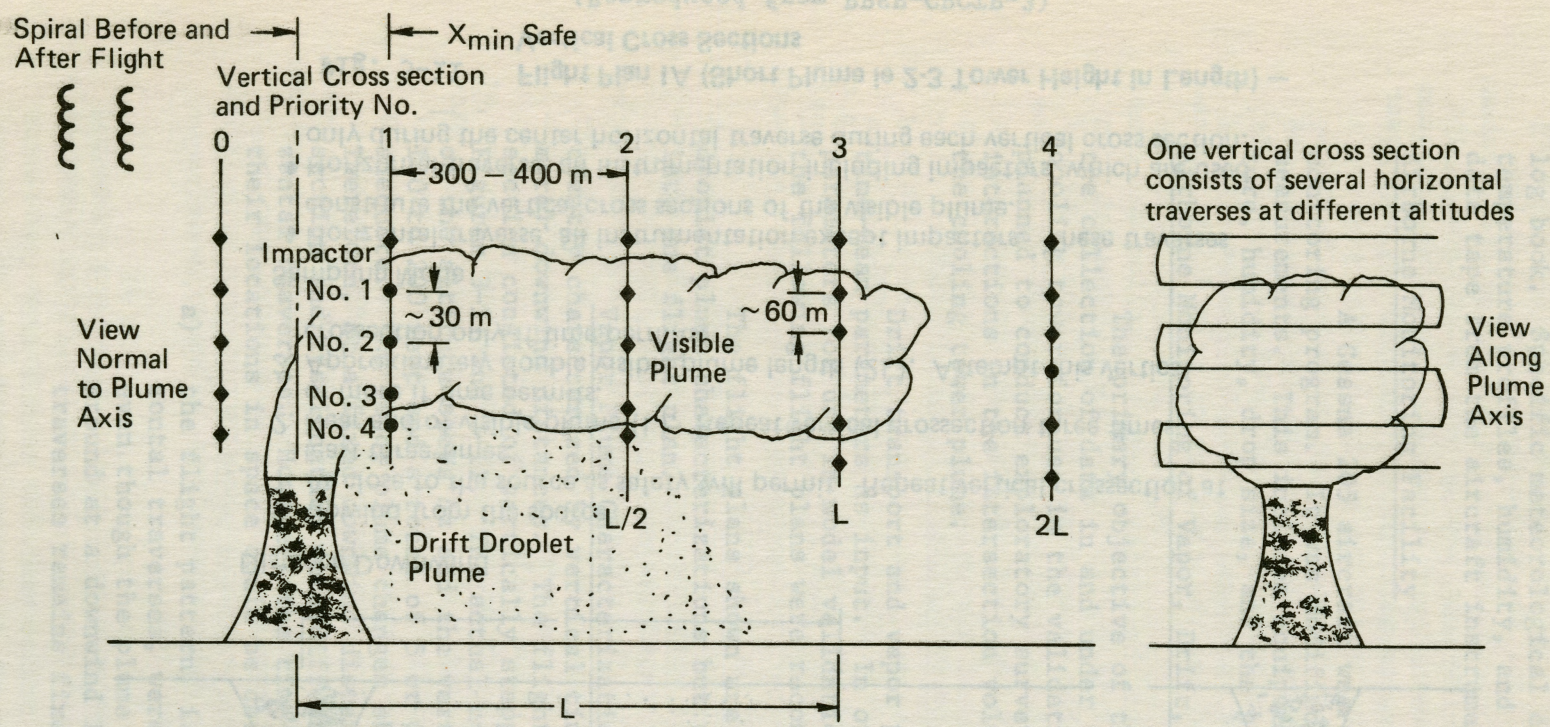
Sampling Mode

- ♦ Horizontal traverse, all instrumentation except impactors. These traverses constitute the vertical cross sections of the visible plume.
- ● Horizontal traverse, all instrumentation including impactors, which are used only during the center horizontal traverse during each vertical cross section.

Fig. 3-11 **Flight Plan IA (Short Plume ie 2-3 Tower Height in Length) — Vertical Cross Sections**

(Reproduced from PPSP-CPCTP-3)

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Distance Downwind

0. Upwind from the source.
1. As close to the source as safety will permit. Repeat vertical cross section at least three times.
2. Approximate midpoint of visible plume (L/2). If time permits repeat this vertical cross section three times.
3. Near end of visible plume (L).
4. Approximately double visible plume length (2L).

Sampling Mode

- ♦ Horizontal traverse, all instrumentation except impactors. These traverses constitute the vertical cross sections of the visible plume.
- ● Horizontal traverse, all instrumentation including impactors, which are used only during the center horizontal traverse during each vertical cross section.

Fig. 3-12 Flight Plan IB — (Long Plume) Vertical Cross Sections

(Reproduced from PPSP-CPCTP-3)

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b) the vertically-stepped horizontal traverses were flown several times within a time frame of, at least, some 15 to 20 minutes. This should be the minimum meteorological time scale for the definition of time-mean plume parameters.

Ideally, we tried to characterize at least three vapor plume cross-sections within a 60- to 90-minute time frame. The shorter the time frame the more steady are the meteorological conditions which will later facilitate the construction of the time-mean plume geometry.

The first cross-section was made as close to the cooling tower as safety considerations permitted. The downwind distances of the other cross-sections depend primarily on meteorological conditions and they were determined on site prior to each test program.

Drift Droplet Plume Characterization - The drift droplet plume was characterized in both horizontal and vertical cross-sections. Note that the data collection instrumentation cross-section was very small. This placed severe restrictions on the statistical accuracy of the data.

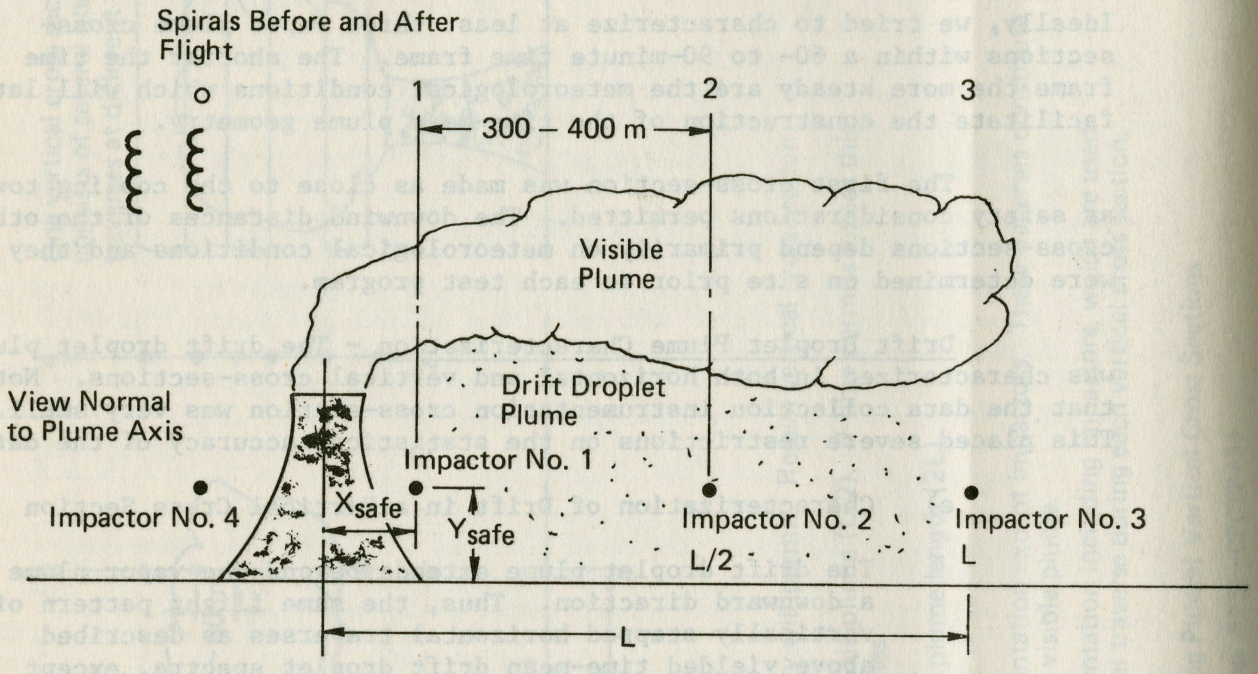
a) Characterization of Drift in a Vertical Cross Section

The drift droplet plume extends beyond the vapor plume in a downward direction. Thus, the same flight pattern of vertically stepped horizontal traverses as described above yielded time-mean drift droplet spectra, except that the grid of horizontal traverses had to be extended downward as close to the ground as safety will permit in order to cover as much of the drift plume as possible.

b) Characterization of Drift in a Horizontal Cross Section

The objective of this flight pattern was to obtain the time-mean drift droplet spectra at a fixed altitude as a function of downwind distance. This data allows the calculation of the time-mean drift droplet flux (deposition) through the horizontal plane. Figure 3-13 shows the flight pattern which consists of horizontally stepped horizontal traverses. This flight pattern was identical to the pattern described to characterize a vertical cross-section, except that it is executed in the x-y-plane instead of in the y-z-plane. The flight pattern had to be fixed in space and repetitiously flown as described before.

The altitude of the horizontal plane was made as low as safety considerations would allow. The downwind spacing Δx of the horizontal traverses depended primarily on meteorological conditions and had to be decided upon on site.



Distance Downwind

0. Upwind from the source.
1. As close to the source as safety will permit.
2. Approximate midpoint of visible plume (L/2).
3. Near end of visible plume (L).

Repeat flight plan at least three times

A. Just underneath the visible plume
B & C. Midway between the bottom of the visible plume and as close to the ground as safety will permit.
D. As close to the ground as safety will permit.

Sampling Mode

- Horizontal traverse. all instrumentation a set of traverses constitute a vertical cross section of the drift droplet plume. Each cascade impactor sampling will take an integrated sample of all traverses at each vertical cross section.

Fig. 3-13 **Flight Plan II – Horizontal Drift Droplet Plume**
(Reproduced from PPSP-CPCTP-3)

Monitoring of the Chemical Interaction Zone - The MRI aircraft is equipped to monitor H_2SO_4. By the use of vertical cross-section traverses, similar to those used in vapor plume characterization, chemical interaction surveys were made under meteorological conditions causing intersection of fossil stack plumes and the cooling tower vapor plume. The flight plan for these tests is shown as Figure 3-14.

Aircraft Sampling Plan

As part of the seasonal intensive testing, Meteorology Research, Inc. (MRI) conducted sampling operations in both the cooling tower plume alone and in the stack/cooling tower plume interaction zone. In addition a small sampling effort was conducted within the Unit #3 stack plume alone. This is considered to be the best method of assessing the characteristics of H_2SO_4 production from scrubber/fossil fuel emission interactions.

The sampling plan given in Figures 3-11 and 3-12 was designed for vapor plume characterizations. The basic plan, without drift drop measurements, was also applied to smoke plume characterization if performed. It was assumed that for normal test cases there would be some wind that would impart a horizontal velocity to the plume.

Data Collection from Airborne Monitoring Flights

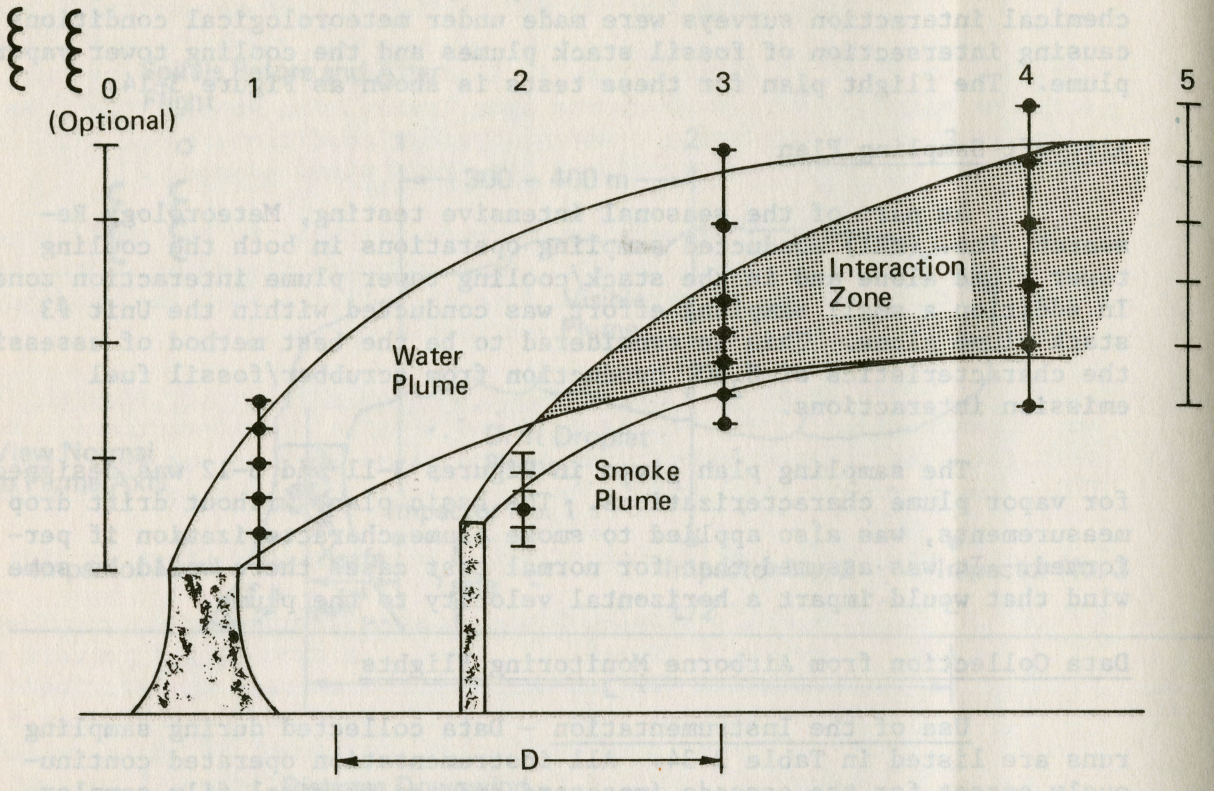
Use of the Instrumentation - Data collected during sampling runs are listed in Table 3-34. All instrumentation operated continuously except for the cascade impactors and the chemical film sampler. The impactors and film sampler were used to collect an integrated sample for each complete plume cross-section (impactors are limited to four cross-sections per test flight). These data are reported in References 3-24 and 3-28.

Plume Photography

In addition to parameters defining composition of the plume, physical dimensions of the time-mean plume are also extremely useful. Mathematical models of plume behavior, which can predict impacts of plumes on nearby systems, rely on such measurments for their verification. Two photographic systems were utilized during seasonal intensive testing at Chalk Point to provide this essential data. These are described below.

35-mm Plume Photography - The vertical plane time-averaged plume outline was obtained during the seasonal test periods by means of the single-camera system. The sites for this system are shown in Figure 3-15. Two-dimensional time-mean plume outlines have been obtained by averaging a number of plume photographs taken from a single camera station. The plume was photographed every two minutes, with twenty minutes as the minimum time for defining a time-mean plume.

Spiral at Begin and End of Flight



Distance Downwind

0. Upwind from source.
1. As close to water plume source as safety permits. Use Impactor No. 1
2. As close to *smoke* plume source as safety permits. Use Impactor No. 2
3. Slightly downwind from the beginning of interaction zone. Use Impactor No. 3
4. Selected locations in the interaction zone based on the existing meteorological environment. Use Impactor No. 4
5. Selected locations in the interaction zone based on the existing meteorological environment.

Sampling Mode

- Horizontal traverse, all instrumentation (limited to 4 impactors per flight) and on impactor per vertical cross section.

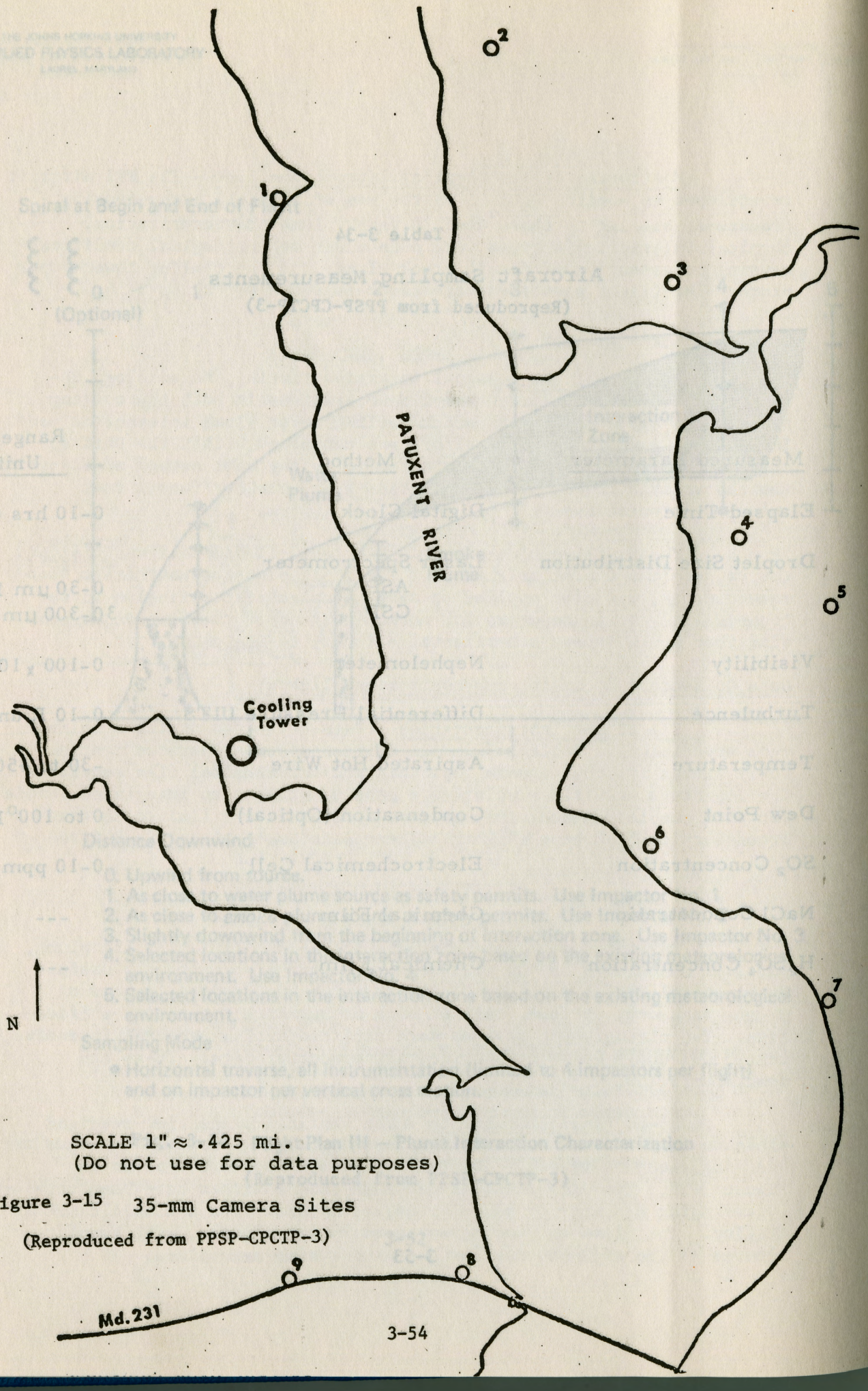
Fig. 3-14 **Flight Plan III — Plume Interaction Characterization**

(Reproduced from PPSP-CPCTP-3)

Table 3-34

Aircraft Sampling Measurements
(Reproduced from PPSP-CPCTP-3)

Measured Parameter	Method	Range and Units
Elapsed Time	Digital Clock	0-10 hrs (sec)
Droplet Size Distribution	Laser Spectrometer	
	ASP	0-30 μm Dia.
	CSP	30-300 μm Dia.
Visibility	Nephelometer	0-100 $\times 10^{-4}$ m^{-1}
Turbulence	Differential Pressure UITS	0-10 R units
Temperature	Aspirated Hot Wire	-30 to +50°C
Dew Point	Condensation (Optical)	0 to 100°F
SO_2 Concentration	Electrochemical Cell	0-10 ppm
NaCl Concentration	Chemical Film	---
H_2SO_4 Concentration	Chemical Film	---



SCALE 1" ≈ .425 mi.
(Do not use for data purposes)

Figure 3-15 35-mm Camera Sites

(Reproduced from PPSP-CPCTP-3)

Time-Lapse Photography - In addition to the 35-mm system ESC operated continuously a super 8-mm time lapse movie system. The purpose of this system is primarily archival.

Ground Level Salt Measurements

The Primary data for use in checking the impact predicted by the various salt drift models is the measure of salt reaching the ground. At least four different measures of this quantity appear in the model literature; namely 1) ground level salt concentration, 2) ground level deposition, 3) ground level number/density flux, and 4) ground level number concentration. This program has emphasized the use of ground level concentration up to this time.

Airborne Particle Sampling (Ground Level) - The Airborne Particle Sampling (APS) Program had 2 major objectives. One was to determine the background levels of the airborne salt concentration (mass of salt per unit volume of air) naturally occurring in the vicinity of the Chalk Point site and to identify the variability of these levels as a function of meteorology and location within the Chalk Point environs. The other objective was to measure the contributions of the cooling tower to the ambient salt concentration. To satisfy the first objective (background characterization), six sampling stations were employed in directions North, East, South and West of the cooling tower and power plant. Each station is identified in Figure 3-16 by a digit and letter. The digit indicates the number of miles and the letter, the direction of the station from the plant. The remaining stations are 3N, 1E, 3E, 3S, and 6W. These APS stations were located on six of the plots maintained by the University of Maryland as part of the CPCTP for Agronomy and Botany studies. Operation of these stations commenced in May 1974. A description of the APS equipment and a discussion of the resulting data are included in Reference 3-22.

Since the cooling tower began operation in May 1974, the second objective of this sampling program was to determine the contributions of salt in the ambient air attributable to this operation (source delineation). For this evaluation more sampling stations were employed in a network which favors the dominant wind directions. By placing the stations in sectors predominately downwind of the tower, the probability of measuring source contributions was enhanced. In addition to the use of mobile station sites (MNW and MNE) shown in Figure 3-17 nearest the tower, the other station locations were subject to examination and change of location based on the results of preliminary source and contribution data. Finally, the network shown in Figure 3-17 provided for the simultaneous acquisition of background (upwind) and source influenced (downwind) data. For example, with a SSE wind prevailing, the APS stations to the NNW of the tower would be monitored for source data while monitoring essentially simultaneously a station upwind (e.g. 1S or 1SE) for determination of background salt characterizing the sampling period.

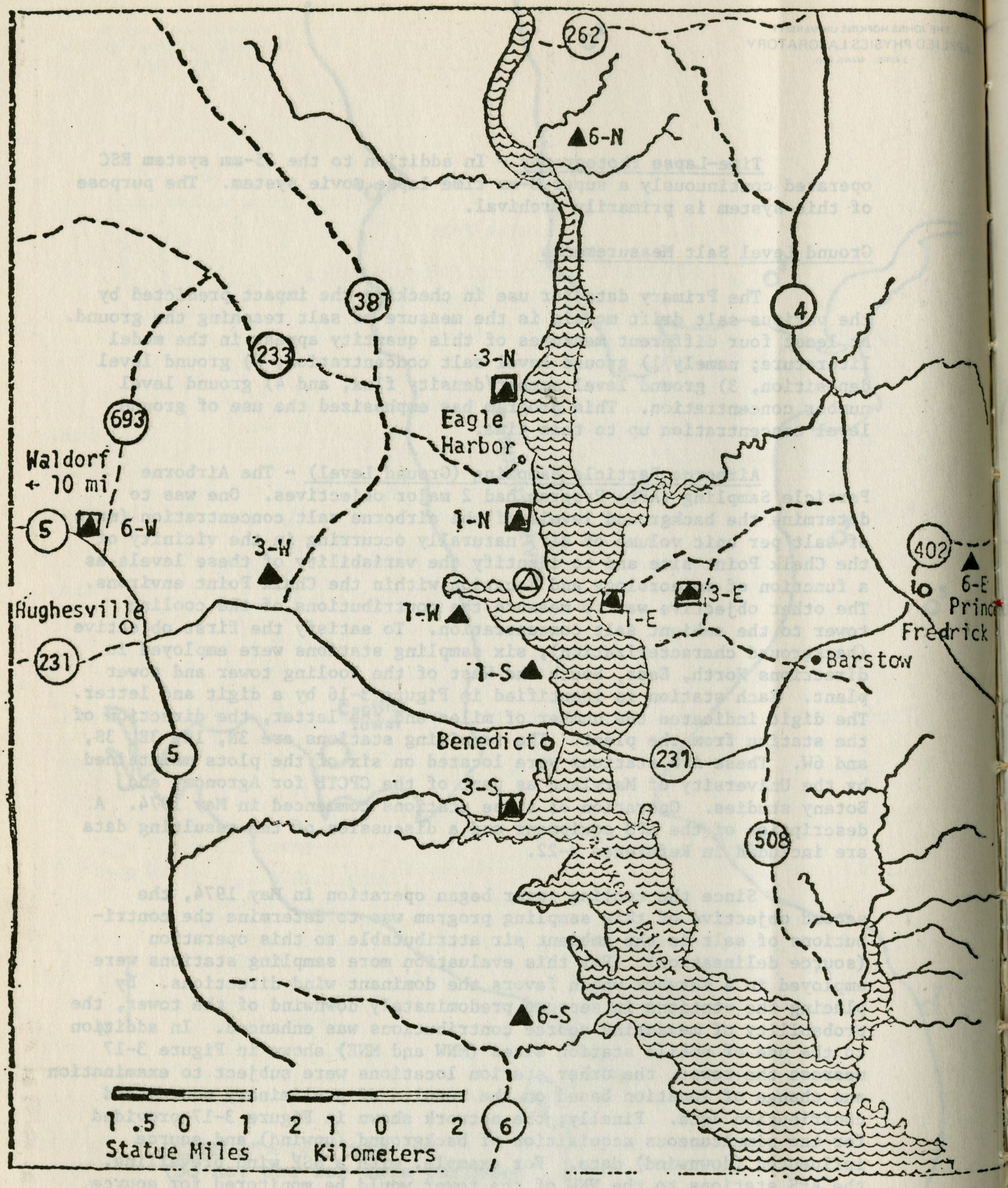


Figure 3-16

LOCATION OF APS STATIONS
BACKGROUND CHARACTERIZATIONS

(Reproduced from PPSP-CPCTP-3)

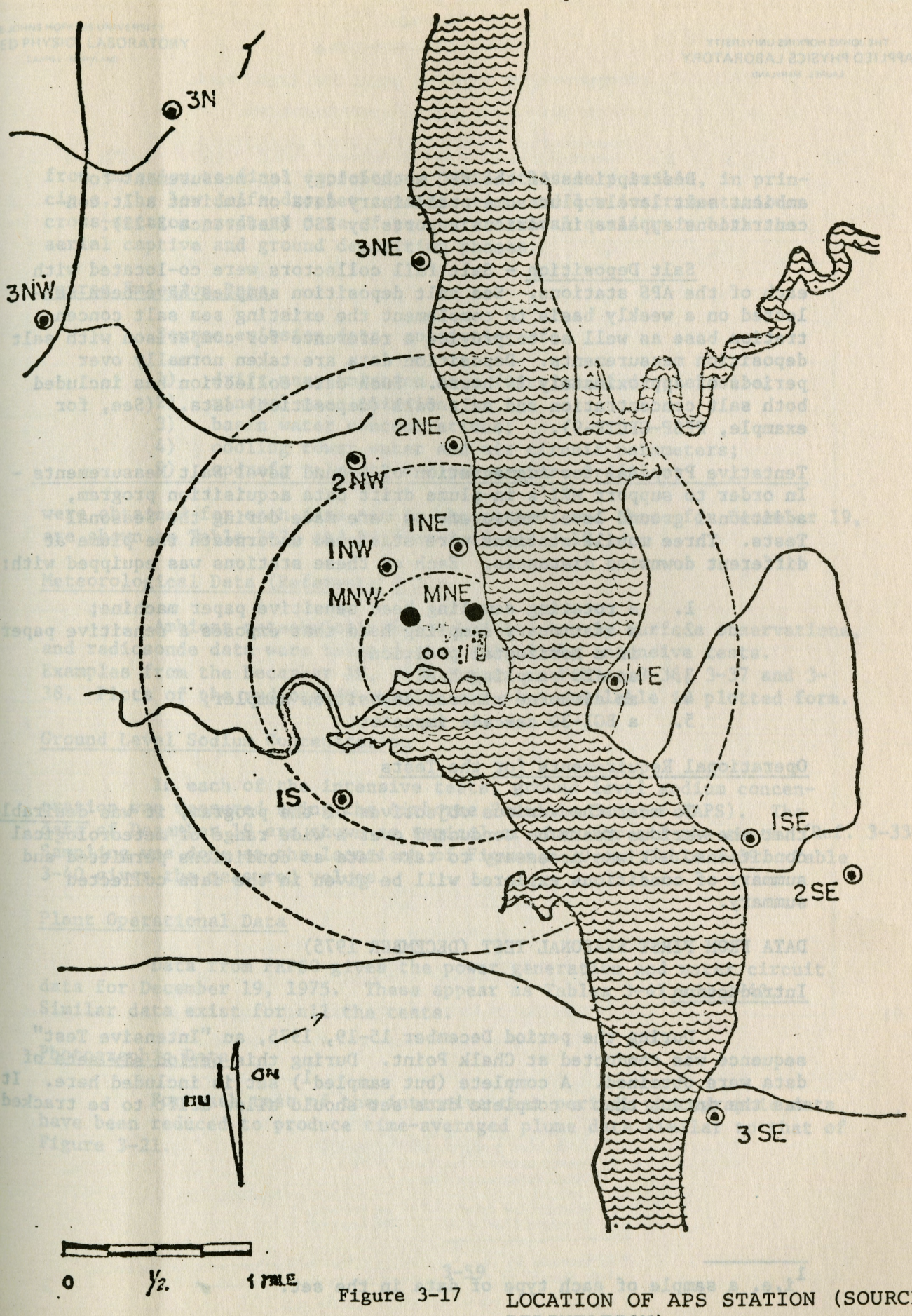


Figure 3-17 LOCATION OF APS STATION (SOURCE DELINEATION)

(Reproduced from PPSP-CPCTP-3)

Descriptions of the ESC methodology for measurement for ambient salt levels plus some preliminary data on ambient salt concentrations appears in various reports by ESC (Reference 3-22).

Salt Deposition - Salt fall collectors were co-located with each of the APS stations. Sea salt deposition samples have been collected on a weekly basis to complement the existing sea salt concentration base as well as to provide a reference for comparison with salt deposition measurements. Deposition data are taken normally over periods of approximately 24 hours. Such data collection has included both salt concentration and salt fall (deposition) data. (See, for example, PPSP-CPCTP-9).

Tentative Proposal for Augmentation of Ground Level Salt Measurements - In order to support MRI's in-plume drift data acquisition program, additional ground level measurements were made during the Seasonal Tests. Three mobile stations were stationed underneath the plume at different downwind distances. Each of these stations was equipped with:

1. a rotating sampling head sensitive paper machine;
2. a stationary sampling head that exposes a sensitive paper in a horizontal position;
3. an APS sampling head;
4. an airborne mineral deposition sampler;
5. a BGI-30 cascade impactor.

Operational Requirements for the Tests

To meet the various objectives of the program, it was desirable that the various tests be conducted over a wide range of meteorological conditions. It was necessary to take data as conditions permitted and summary of conditions explored will be given in the data collected summary.

DATA FROM FIRST SEASONAL TEST (DECEMBER 1975)

Introduction

During the period December 15-19, 1975, an "Intensive Test" sequence was conducted at Chalk Point. During this period six sets of data were obtained. A complete (but sampled[1]) set is included here. It was the intent that a complete data set should allow drift to be tracked

[1] i.e. a sample of each type of data in the set.

from emission to final deposition. While this is possible, in principle, the low drift droplet concentration and low instrumentation cross-section produced data of poor statistical quality in both the aerial captive and ground deposition phases.

Source Emission Data

Source emission data, consisting of:

1) drift mass emission as a function of droplet size;
2) mineral mass emission;
3) basin water concentrations;
4) cooling tower water and air circuit parameters;
5) updraft velocity and temperature profiles;

were obtained for each data set in the period, and those for December 19, are shown as Table 3-35 and Figures 3-18 and 3-19.

Meteorological Data (Reference 3-23)

Ambient meteorological tower data, hourly surface observations, and radiosonde data were taken during all of the intensive tests. Examples from the December 19, 1975 appear as Tables 3-36, 3-37 and 3-38. Plots of the radiosonde results are also available in plotted form.

Ground Level Sodium Concentration

In each of the intensive tests, ground level sodium concentration was measured using the Airborne Particle Sampler (APS). The data of December 19 are shown as typical of that for all the tests. (Ref. 3-33) Sampling was done at the locations of Figure 3-20 and Table 3-39. Table 3-40 gives the measured values.

Plant Operational Data

Data from PEPCO gives the power generation and water circuit data for December 19, 1975. These appear as Tables 3-41 and 3-42. Similar data exist for all the tests.

Photographic Data

For each test of the intensive test period, photographic data have been reduced to produce time-averaged plume data similar to that of Figure 3-21.

TABLE 3-35

(Excerpted from PPSP-CPCTP-3)

CHARACTERIZATION OF THE UNIT #3 NATURAL DRAFT COOLING TOWER.

Drift Mass Emission as a Function of Droplet Size.

Date and Time: December 19, 1975, 8:31 - 12:15 EST
Measurement Mode: Equal Area Traverse
Measurement Location: North-South Diameter, Upper Level
Cooling Tower Cross-Sectional Area at the Measurement Location: 2050m²
These Data were Acquired by: PILLS and SP

I	d' μm	d" μm	Δd μm	d_c μm	ΔD gm/s	ΔD/D %
1	10	30	20	20	7.11	11.1
2	30	50	20	40	8.28	12.9
3	50	70	20	60	4.81	7.5
4	70	90	20	80	4.29	6.7
5	90	110	20	100	4.33	6.8
6	110	130	20	120	4.14	6.5
7	130	150	20	140	3.84	6.0
8	150	180	30	165	4.97	7.8
9	180	210	30	195	3.79	5.9
10	210	240	30	225	2.81	4.4
11	240	270	30	255	1.86	2.9
12	270	300	30	285	1.17	1.8
13	300	350	50	325	1.13	1.8
14	350	400	50	375	0.94	1.5
15	400	450	50	425	0.89	1.4
16	450	500	50	475	0.89	1.4
17	500	600	100	550	1.74	2.7
18	600	700	100	650	1.71	2.7
19	700	800	100	750	1.57	2.4
20	800	900	100	850	1.40	2.2
21	900	1000	100	950	1.18	1.8
22	1000	1100	100	1050	0.88	1.4
23	1100	1200	100	1150	0.44	0.7
					D = ΣΔD = 64.17	100.3*

Mass Median Diameter: 126μm

* This column does not add up to 100% due to rounding.

Mineral Mass Emissions[1]

Date and Time, Measurement Mode and Location Same as A. 1.
These Data were Acquired by: Isokinetic Sampling System

Sodium emission: 0.325 gm/s
Magnesium emission: 0.048 gm/s

Basin Water Concentrations:

Sodium concentration: 2680 mg/liter
Magnesium concentration: 370 mg/liter

Selected Cooling Tower Water and Air Circuit Parameters

The following data are averaged over the time period of the Equal Area Traverse:

Updraft velocity:	4.61 m/s,	standard deviation:	1.03m/s
Wet bulb temperature:	16.0°C[2] ,	" " :	1.49°C
Dry bulb temperature:	16.2°C ,	" " :	1.46°C
Hot water temperature:	27.7°C ,	" " :	0.43°C
Cold water temperature:	14.3°C ,	" " :	0.37°C
Makeup water temperature:	9.8°C ,	" " :	0.31°C
Circulating water flow rate:	984.1m³/min or 260,000gpm(See Footnote [3])		
Makeup flow rate:	See Footnote [4]		
Blowdown flow rate:	See Footnote [4]		

[1] As measured by IK only. Backup filter collections were in the average less than 5% of the IK collections and are neglected.

[2] Wet bulb temperature sensor not operational.

[3] Design value. Sensor presently not installed.

[4] Sensors presently not installed.

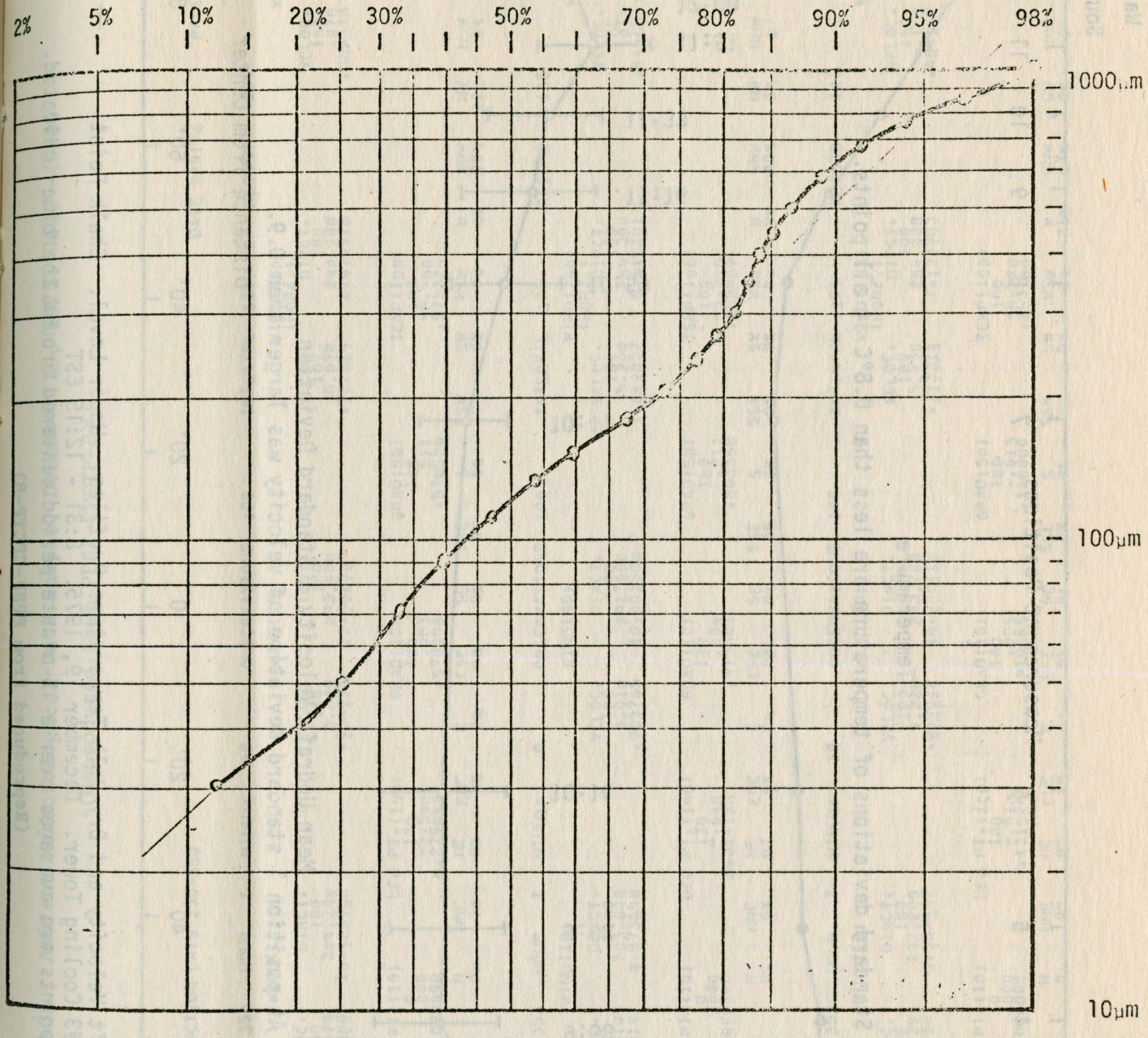


Figure 3-18. Drift Mass Emission Fraction Below Droplet Diameter Indicated Chalk Point Unit #3 Cooling Tower, December 19, 1975. 8:31 - 12:15 EST
(Reproduced from PPSP-CPCTP-8)

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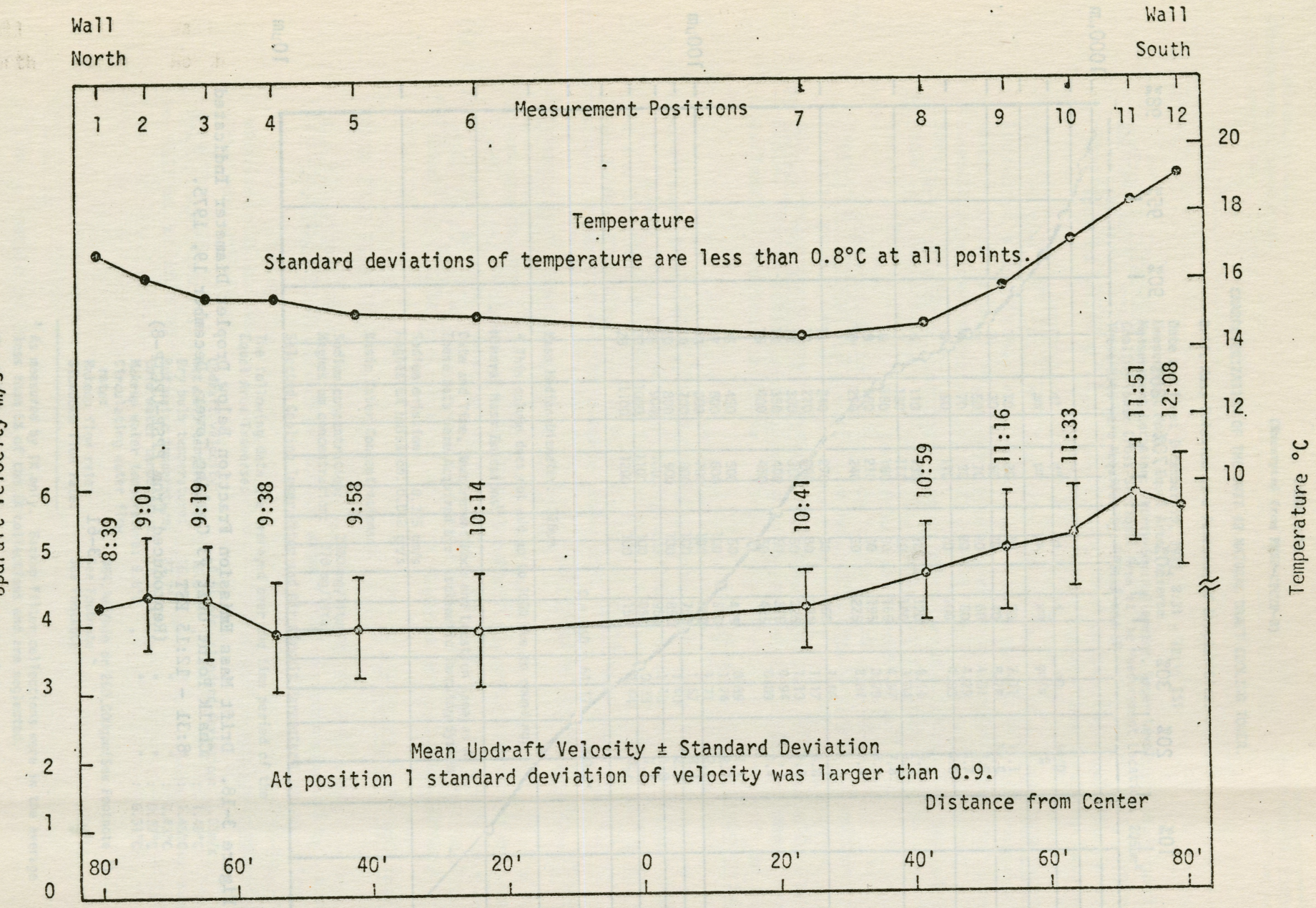


Figure 3-19 Updraft Velocity and Dry Bulb Temperature Profiles. Upper Level. Chalk Point Unit #3 Cooling Tower. December 19, 1975. 8:31 - 12:15 EST
Data points are averages over a 15-minute period centered around the time indicated.

(Reproduced from PPSP-CPCTP-8)

Table 3-36. Ambient Meteorological Data Sample, December 19, 1975: 0600 - 0800

(Reproduced from PPSP-CPCTP-8)

CHALK POINT DATA REDUCTION DAYS 350-353 DATE 020176 PAGE 51

AVERAGE TIME - DAY 353 HOUR 6 MINUTE 30 OBSERVATIONS 180 INTERVAL 124 RECORD 124

	WIND(10) VELOC.	WIND(10) DIRCT.	WIND(50) VELOC.	WIND(50) DIRCT.	WIND(100) (HORZ.) VELOC.	WIND(100) (HORZ.) DIRCT.	WIND(100) (VERT.) VELOC.	WIND(100) (VERT.) DIRCT.
OBS.	180	180	180	180	180	180	180	180
MEAN	2.370	304.200	3.820	293.400	5.090	292.400	.070	.700
SIGMA	.821080	15.425952	.930936	13.862539	.927524	8.979978	.582323	6.653570

	DEW PT.(10)	DEW PT.(100)	GRAD(10)	GRAD(50)	TEMP(100)
OBS.	0	180	180	180	180
MEAN	.000	-5.550	.003	.011	-8.460
SIGMA	.000000	6.279642	.590508	.570526	.575326

WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	78%	12%	0%

AVERAGE TIME - DAY 353 HOUR 7 MINUTE 0 OBSERVATIONS 180 INTERVAL 125 RECORD 125

	WIND(10) VELOC.	WIND(10) DIRCT.	WIND(50) VELOC.	WIND(50) DIRCT.	WIND(100) (HORZ.) VELOC.	WIND(100) (HORZ.) DIRCT.	WIND(100) (VERT.) VELOC.	WIND(100) (VERT.) DIRCT.
OBS.	180	180	180	180	180	180	180	180
MEAN	1.910	303.000	3.910	291.600	5.230	289.300	.010	.100
SIGMA	.640312	9.473648	.980765	10.002500	1.049857	6.915201	.446654	4.990942

	DEW PT.(10)	DEW PT.(100)	GRAD(10)	GRAD(50)	TEMP(100)
OBS.	0	179	179	180	180
MEAN	.000	-.640	.004	.011	-8.540
SIGMA	.000000	3.314136	.413084	.803368	.385487

WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	9%	88%	2%	0%

AVERAGE TIME - DAY 353 HOUR 7 MINUTE 30 OBSERVATIONS 180 INTERVAL 126 RECORD 126

	WIND(10) VELOC.	WIND(10) DIRCT.	WIND(50) VELOC.	WIND(50) DIRCT.	WIND(100) (HORZ.) VELOC.	WIND(100) (HORZ.) DIRCT.	WIND(100) (VERT.) VELOC.	WIND(100) (VERT.) DIRCT.
OBS.	180	180	180	180	180	180	180	180
MEAN	2.020	297.200	4.220	293.700	5.430	284.000	-.160	-1.600
SIGMA	.492136	9.552407	.869022	10.080112	.743371	7.123903	.404149	5.488524

	DEW PT.(10)	DEW PT.(100)	GRAD(10)	GRAD(50)	TEMP(100)
OBS.	0	180	180	180	180
MEAN	.000	-.810	.005	-.013	-8.570
SIGMA	.000000	.131528	.219545	.110000	.253180

WIND FREQUENCY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	31%	67%	0%	0%

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Table 3-37
(Reproduced from PPSP-CPCTP-4 Rev)
HOURLY SURFACE OBSERVATIONS

PEPCO POWER PLANT CHALK POINT, MD.

DAY	DATE	TIME (EST)	PRESSURE mb	TEMP °C	RH %	WATER VAPOR DENSITY g/m^3	WIND DIR. deg	WIND SPEED m/sec	VISIBILITY km	CEILING HEIGHT m	TOTAL CLOUD COVER Tenths	TURNER'S STABILITY CLASS	R/S TEMP LAPSE RATE ($\Delta T/\Delta Z$) 100-500m °C/100m
Friday	12-19-75	0700	1026.3	-6.7	46	1.38	340	2.5	4.0	UNL*	4	4	
		0800	1027.0	-7.1	46	1.35	350	2.5	8.0	2100	6	4	-1.03
		0900	1027.9	-6.4	44	1.34	350	4.4	16.0	UNL	4	4	
		1000	1027.9	-4.9	40	1.38	340	3.6-4.4	16.0	3000	6	4	
		1100	1028.0	-4.8	36	1.25	350	3.6-4.4	16.0	3000	6	4	
		1200	1027.0	-3.0	34	1.33	320	3.6-4.4	16.0	UNL	3	4	-0.64

* UNLIMITED CEILING (Ceiling is defined as height of cloud cover 0.5 or greater)

Table 3-38. Radiosonde Data

(Reproduced from PPSP-CPCTP-4 Rev)

CHALK POINT MD. 38 DEC. 19,1975 1205 EST

INPUT DATA

CALIBRATION			HT	SURFACE DATA				
T-ORD	T	RH-ORD	MSL	WD	WS	P	T	RH
73.3	30.0	70.4	8.	300.	4.6	1027.2	-3.4	31.9

TIME FOR EACH CONTACT POINT (IGNORE VALUES NEAR BEGINNING AND END)

-20.00	-19.00	0.0	0.39	0.92	1.34	1.68	1.97	2.30	2.64	2.97	3.24	3.48	3.78	4.07	4.38	4.67	4.92	5.35	5.73
6.35	6.92	7.41	8.05	8.67	9.67	10.67	11.67	12.67	13.67	14.67	15.67	16.67	17.67	18.67	19.67	20.67	21.67	22.67	23.67

PRESSURE FOR EACH CONTACT POINT

1058.8	1046.3	1027.2	1021.8	1009.8	994.8	983.8	971.8	960.8	948.8	935.3	923.8	912.8	902.3	891.3	877.8	866.8	856.3	845.8	835.8
822.8	812.3	801.8	791.8	781.8	769.3	759.3	749.8	740.3	730.8	721.3	711.8	701.8	692.8	683.8	672.8	663.8	654.8	645.8	636.8

TIME (MIN)	HEIGHT (M)	PRES (MB)	TEMP (ORD)	TEMP (DEG C)	VIRTUAL TEMP (DEG C)	POTENTIAL TEMP (DEG K)	RH (ORD)	RH (PCT)	DP (DEG C)	DPD (DEG C)	VAPOR PRES (MB)	VAPOR CONC. (C/M3)	MIXING RATIO (G/KG)	DENSITY DRY (KG/M3)	DENSITY MOIST (KG/M3)
0.0	8.0	1027.2	54.7	-5.3	-5.3	265.8	80.4	20.1	-24.7	19.4	0.82598	0.6685	0.5025	1.3367	1.3363
0.05	13.3	1026.5	54.2	-6.1	-6.0	265.1	80.3	20.5	-25.2	19.1	0.79381	0.6443	0.4833	1.3396	1.3392
0.12	20.7	1025.5	54.0	-6.4	-6.3	264.9	80.3	20.5	-25.4	19.0	0.77637	0.6309	0.4731	1.3398	1.3394
0.19	28.1	1024.6	54.0	-6.4	-6.3	264.9	79.9	21.8	-24.8	18.4	0.82356	0.6692	0.5024	1.3386	1.3382
0.27	36.5	1023.5	54.1	-6.2	-6.2	265.2	79.5	23.0	-24.1	17.8	0.87855	0.7135	0.5365	1.3364	1.3359
0.34	43.9	1022.5	54.0	-6.4	-6.3	265.1	79.3	23.6	-23.9	17.5	0.89069	0.7237	0.5444	1.3358	1.3354
0.40	50.9	1021.6	53.6	-7.0	-6.9	264.6	79.5	23.0	-24.7	17.7	0.83073	0.6765	0.5082	1.3376	1.3372
0.47	63.0	1020.0	53.3	-7.4	-7.4	264.2	80.0	21.5	-25.8	18.4	0.75108	0.6127	0.4602	1.3378	1.3374
0.54	75.1	1018.4	53.2	-7.6	-7.5	264.2	79.9	21.8	-25.8	18.2	0.75333	0.6149	0.4623	1.3364	1.3361
0.61	87.2	1016.8	53.3	-7.4	-7.4	264.5	79.5	23.0	-25.1	17.6	0.80333	0.6553	0.4937	1.3336	1.3332
0.67	97.6	1015.5	53.2	-7.6	-7.5	264.4	79.4	23.3	-25.0	17.5	0.80441	0.6566	0.4951	1.3326	1.3322
0.74	109.8	1013.9	52.8	-8.2	-8.1	264.0	79.8	22.1	-26.1	17.9	0.73048	0.5975	0.4502	1.3334	1.3331
0.81	121.9	1012.3	52.9	-8.0	-7.9	264.2	79.5	23.0	-25.5	17.5	0.76820	0.6280	0.4742	1.3306	1.3302
0.89	135.8	1010.5	52.8	-8.2	-8.1	264.2	79.3	23.6	-25.4	17.2	0.77866	0.6370	0.4816	1.3290	1.3286
0.96	152.0	1008.4	52.5	-8.6	-8.5	263.9	79.8	22.2	-26.5	17.9	0.70648	0.5789	0.4378	1.3284	1.3281
1.03	171.2	1005.9	52.6	-8.5	-8.4	264.3	79.5	23.1	-25.9	17.5	0.74289	0.6084	0.4615	1.3244	1.3240
1.10	190.5	1003.4	52.5	-8.6	-8.5	264.3	79.3	23.7	-25.8	17.2	0.75298	0.6170	0.4690	1.3218	1.3214
1.16	207.1	1001.2	52.4	-8.8	-8.7	264.3	79.1	24.2	-25.6	16.9	0.76236	0.6250	0.4758	1.3197	1.3193
1.23	226.5	998.7	52.2	-9.0	-9.0	264.2	79.1	24.2	-25.9	16.8	0.74547	0.6118	0.4665	1.3179	1.3175
1.30	245.8	996.2	52.0	-9.3	-9.3	264.1	79.4	23.4	-26.5	17.2	0.70346	0.5780	0.4413	1.3160	1.3157
1.37	264.5	993.8	52.0	-9.3	-9.3	264.3	79.2	24.0	-26.2	16.9	0.72055	0.5920	0.4531	1.3129	1.3125
1.43	279.6	991.9	51.9	-9.5	-9.4	264.3	79.2	24.0	-26.4	16.9	0.71253	0.5858	0.4489	1.3110	1.3107
1.52	302.3	989.0	51.7	-9.8	-9.7	264.2	79.2	24.0	-26.6	16.9	0.69677	0.5734	0.4403	1.3086	1.3082
1.58	317.4	987.0	51.7	-9.8	-9.7	264.4	78.9	24.8	-26.2	16.5	0.72091	0.5933	0.4564	1.3060	1.3057
1.65	335.2	984.8	51.6	-9.9	-9.8	264.4	78.9	24.8	-26.4	16.5	0.71287	0.5870	0.4524	1.3037	1.3034
1.72	355.7	982.1	51.4	-10.2	-10.1	264.3	78.8	25.1	-26.5	16.3	0.70468	0.5809	0.4484	1.3017	1.3013
1.79	378.5	979.2	51.2	-10.5	-10.4	264.3	78.7	25.4	-26.6	16.1	0.69643	0.5747	0.4444	1.2993	1.2989
1.85	398.0	976.8	51.1	-10.6	-10.6	264.3	78.6	25.7	-26.6	16.0	0.69587	0.5746	0.4452	1.2967	1.2963
1.94	427.4	973.0	50.9	-10.9	-10.8	264.3	78.7	25.4	-27.0	16.1	0.67338	0.5566	0.4324	1.2932	1.2928

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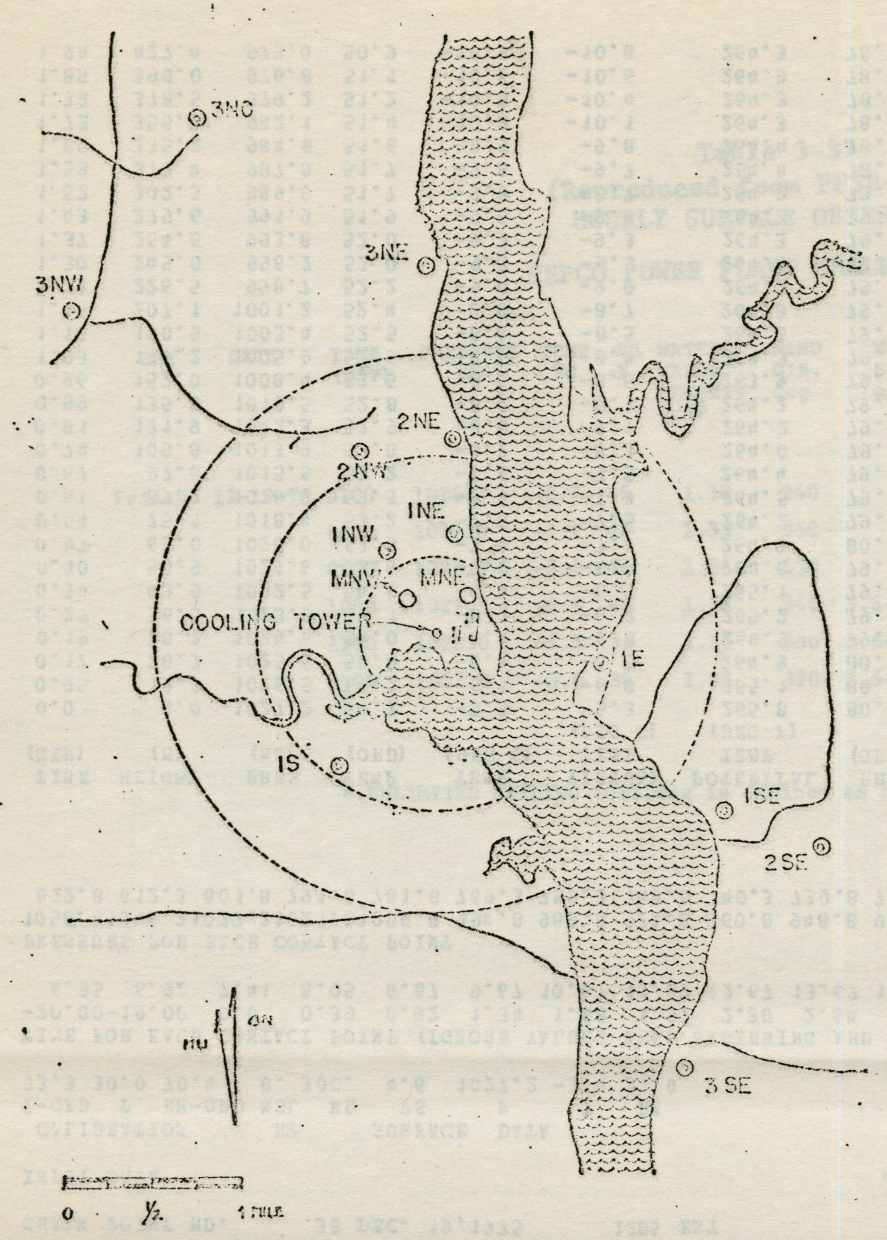


Figure 3-20. APS Station Locations*

*Reproduced from PPSP-CPCTP-12

Table 3-39. APS Station Locations*

Station Designation	Distance from Center of Cooling Tower		Direction[1] from Tower with Respect to Geo. North (degrees)
	Miles	KM	
1NE	0.8	1.3	20
1NW	0.75	1.2	343
2NE	1.33	2.1	10
2NW	1.33	2.1	351
3NE	2.7	4.35	358
3NC	3.4	5.5	333
3NW	3.0	4.8	321
1S	0.95	1.5	194
1E	1.2	1.9	93
1SE	2.3	3.7	116
2SE	2.6	4.2	113
3SE	2.9	4.7	149
MNE[2]	0.22	0.35	53
ME[3]	0.32	0.52	103
MSE[4]	0.20	0.32	145

1. Magnetic North is 7° West of Geographic North in this Area.
2. MNE (Mobile Northeast) was Employed on 12/15 and 12/17/75.
3. ME (Mobile East) was Employed on 12/19/75.
4. MSE (Mobile Southeast) was Employed on 12/16 and 12/18/75.

Table 3-40
(Reproduced from PPSP-CPCTP-8)

GROUND LEVEL SODIUM CONCENTRATION DATA

Date: 12/19/75
Measurement Location: See Table Below, Attached Map and Appendix I.
Measurement Technique: Airborne Particle Sampler

Station	Sodium Concentration ($\mu g/m^3$)	Run Time Start/End EST	Volume Sampled (m^3)	Net Na Collected (μg)
1NE	0.008	10:45/15:57	112.4	0.9
1S	0.009	9:10/13:47	66.4	0.6
1E	0.010	10:07/15:17	114.2	1.1
1SE	0.015	9:50/14:58	114.1	1.7
2SE	0.015	9:37/14:45	113.2	1.7
ME	0.025	9:09/14:20	110.5	2.75

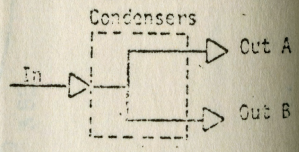
Table 3-41. Plant Operational Data (Reproduced from PPSP-CPCTP-8)

1. Power Output of Unit #3, December 19, 1975

Time Period EST	Average Gross Power Generation MW
7:00 - 8:00	231
8:00 - 9:00	428
-10:00	448
-11:00	589
-12:00	629
-13:00	618
-14:00	605
-15:00	608
-16:00	618
-17:00	632
-18:00	630
-19:00	529
-20:00	628

Note: The above Average Gross Power Generation data were derived from PEPCO's "Chalk Point Unit #3 Periodic Log" which lists the cumulative MWh's generated for each hour.

Table 3-42. Abstract of PEPCO'S Chalk Point Unit 3 Periodic Log (Reproduced from PPSP-CPCTP-8)



December 19, 1975.

Time Period EST	Atmospheric Pressure Inches Mercury	Circulating Water Temperature (Condensers) In °F	Out A °F	Out B °F	Out (Average) °F	Rise °F	Cooling Water Flow Kg/min
7:00 - 8:00	30.37	57.3	81	85	83	25.?	258
- 9:00	30.37	58.0	81	85	83	25.1	257
- 10:00	30.37	57.2	80	84	82	25.1	258
- 11:00	30.38	58.0	81	85	83	25.3	258
- 12:00	30.37	58.3	82	86	84	25.2	258
- 13:00	30.34	58.9	82	86	84	25.1	257
- 14:00	30.32	59.3	82	86	84	25.0	257
- 15:00	30.30	59.8	82	86	84	24.7	257
- 16:00	30.31	60.0	83	87	85	25.2	257
- 17:00	30.32	60.6	84	88	86	25.5	256
- 18:00	30.33	60.5	84	88	86	25.2	256
- 19:00	30.32	60.5	84	88	86	25.2	256
- 20:00	30.35	60.4	84	88	86	25.4	257

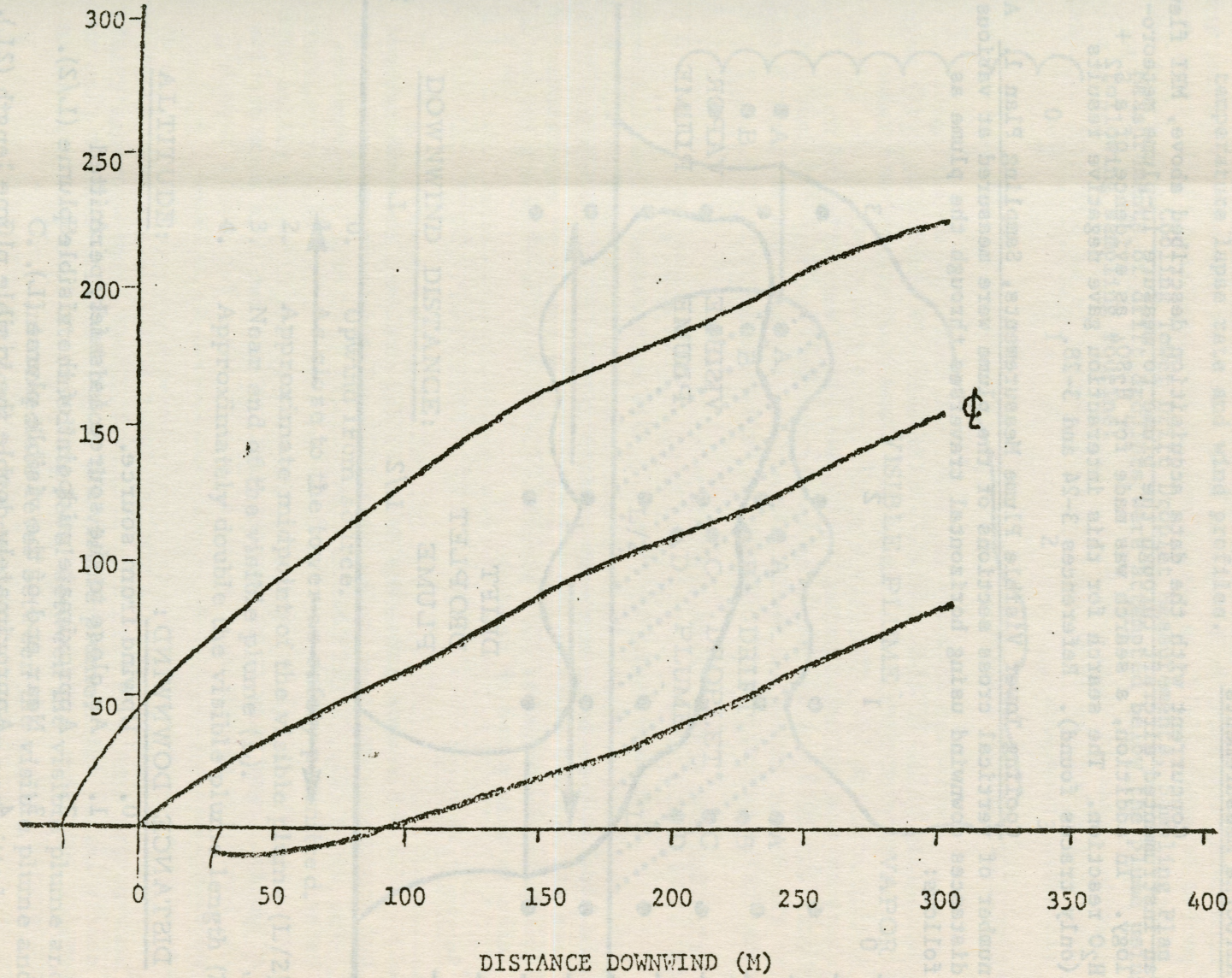


Figure 3-21. Cooling Tower Plume, December 19, 1975, 0946-1218 HRS (EST)

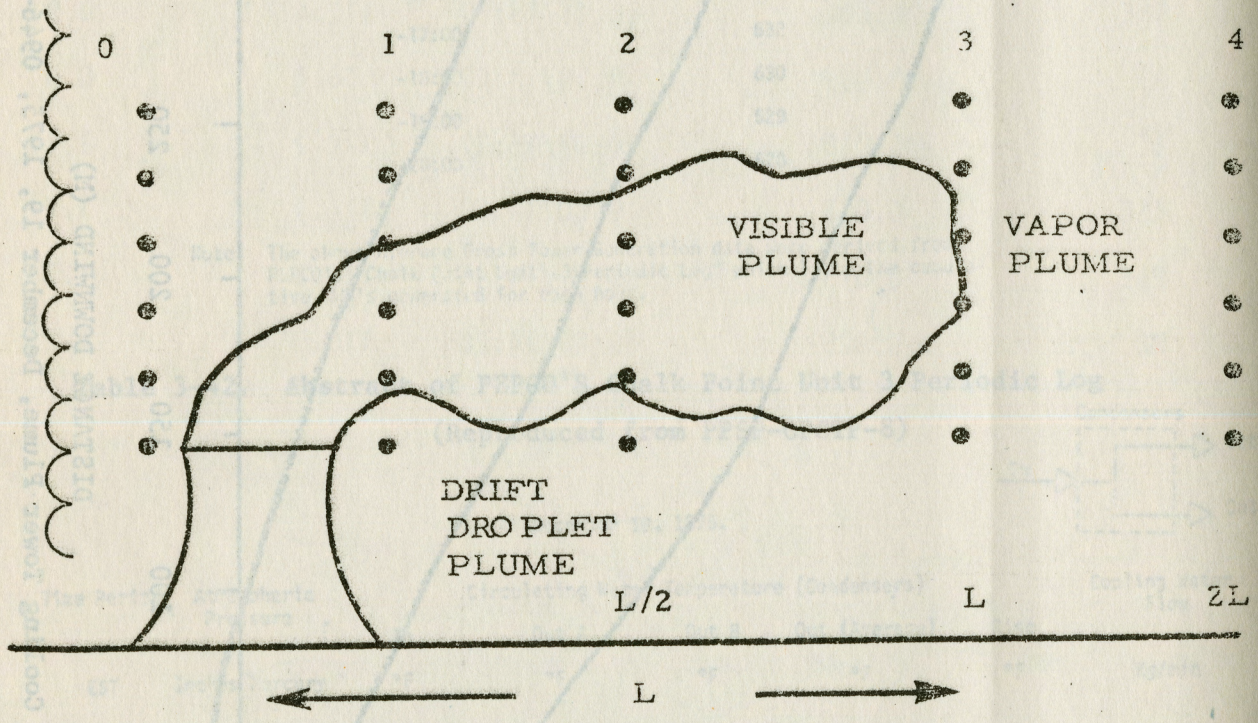
(Reproduced from PPSP-CPCTP-8)

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Airborne Measurements

Concurrent with the data acquisition described above, MRI flew an instrumented aircraft through the plume to measure in-plume meteorology. In addition, a search was made for H_2SO_4 as evidence of a S_2 + H_2O reaction. The search for this interaction gave negative results (only traces found). References 3-24 and 3-28.

Cooling Tower Visible Plume Measurements, Sampling Plan 1. A number of vertical cross sections of the plume were measured at various distances downwind using horizontal traverses through the plume as follows:



DISTANCE DOWNWIND:

0. Upwind from source.
1. As close to the source as safety permitted
2. Approximate midpoint of the visible plume (L/2).
3. Near end of the visible plume (L).
4. Approximately double the visible plume length (2L).

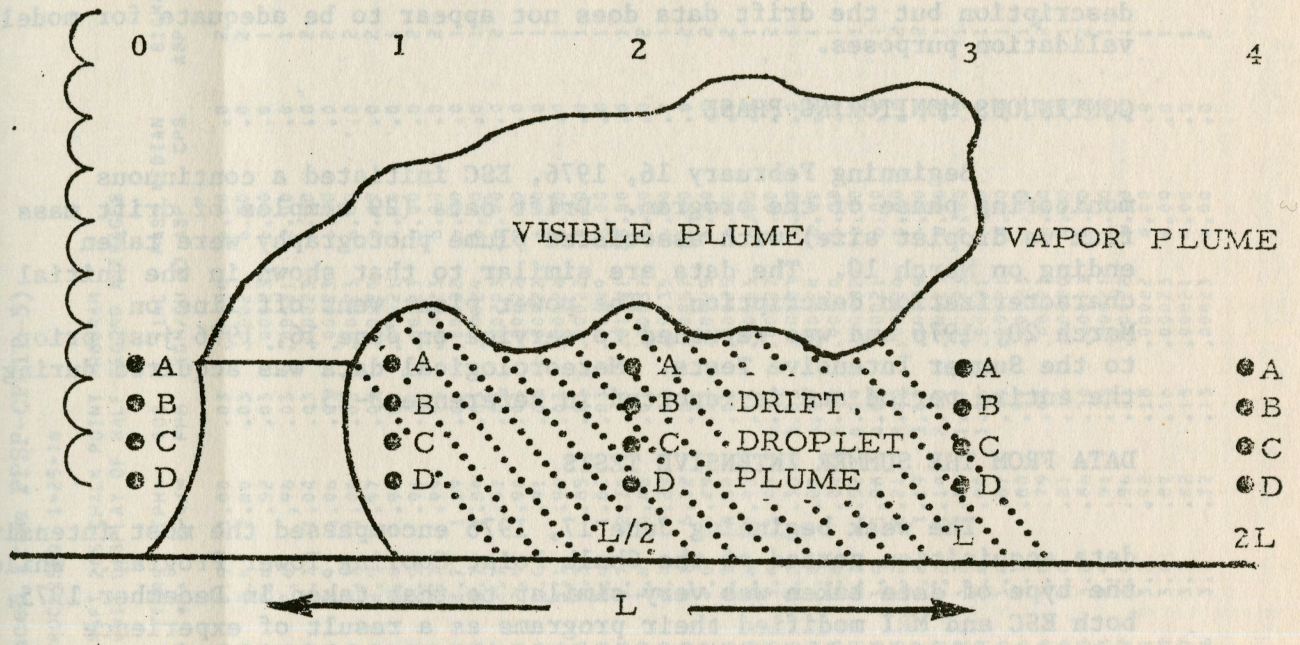
SAMPLING MODE:

- Horizontal traverse.

These tests were accompanied by radiosonde measurements of air temperature lapse rate and wind profiles.

Cooling Tower Drift Droplet Measurements, Sampling Plan 2.

Measurements of drift droplets were attempted below the plume using the following sampling routine:



DOWNWIND DISTANCE:

0. Upwind from source.
1. As close to the tower as safety permitted.
2. Approximate midpoint of the visible plume (L/2).
3. Near end of the visible plume (L).
4. Approximately double the visible plume length (2L).

ALTITUDE:

A. Just below the visible plume.
B. Intermediate level between the visible plume and ground.
C. Intermediate level between the visible plume and ground.
D. As close to the ground as safety permitted.

SAMPLING MODE:

● Horizontal Traverse.
ξ Vertical Temperature Sounding.

MRI Aircraft Sample Data, First Intensive Test - MRI obtained data using automated sampling and data recording systems during the test period December 15-19. A single page of the tabulated flight data, together with time correlated graphical displays, are shown as Table 3-43 and Figure 3-22 and Figure 3-23. Complete data with calibration, and legends appear in Reference 3-24. This information is valuable in plume description but the drift data does not appear to be adequate for model validation purposes.

CONTINUOUS MONITORING PHASE

Beginning February 16, 1976, ESC initiated a continuous monitoring phase of the program. Drift data (29 samples of drift mass flux vs droplet size) with associated plume photography were taken ending on March 10. The data are similar to that shown in the initial characterization description. The power plant went off line on March 20, 1976 and was returned to service on June 16, 1976 just prior to the Summer Intensive Tests. Meteorological data was acquired during the entire period and is reported in Reference 3-25.

DATA FROM THE SUMMER INTENSIVE TESTS

The week beginning June 17, 1976 encompassed the most intensive data acquisition period of the Chalk Point Cooling Tower Program. While the type of data taken was very similar to that taken in December 1975, both ESC and MRI modified their programs as a result of experience gained in the December 1975 program. Table 3-44 is an index to the data taken in this phase of testing.

Source Term Data

The source term data taken by ESC utilized the same methods and equipments utilized in December 1975. The data formats are, therefore, identical. Eight cooling tower source term data sets were obtained. It is notable that the drift emission fluxes were approximately twice the winter values, and that the mass median diameter values were slightly larger than in the winter data. These two data sets provide the basis for establishing seasonal source terms for use in impact modeling.

In addition to the cooling tower source data, three #3 stack source term data sets were also obtained. These, too, showed significantly larger drift mass emission and larger particle content than the winter 1975 data. The summer seasonal Intensive Test data appears in Reference 3-26.

Table 3-43. MRI Meteorological Data (Sample)
(Reproduced from PPSP-CPCTP-5)

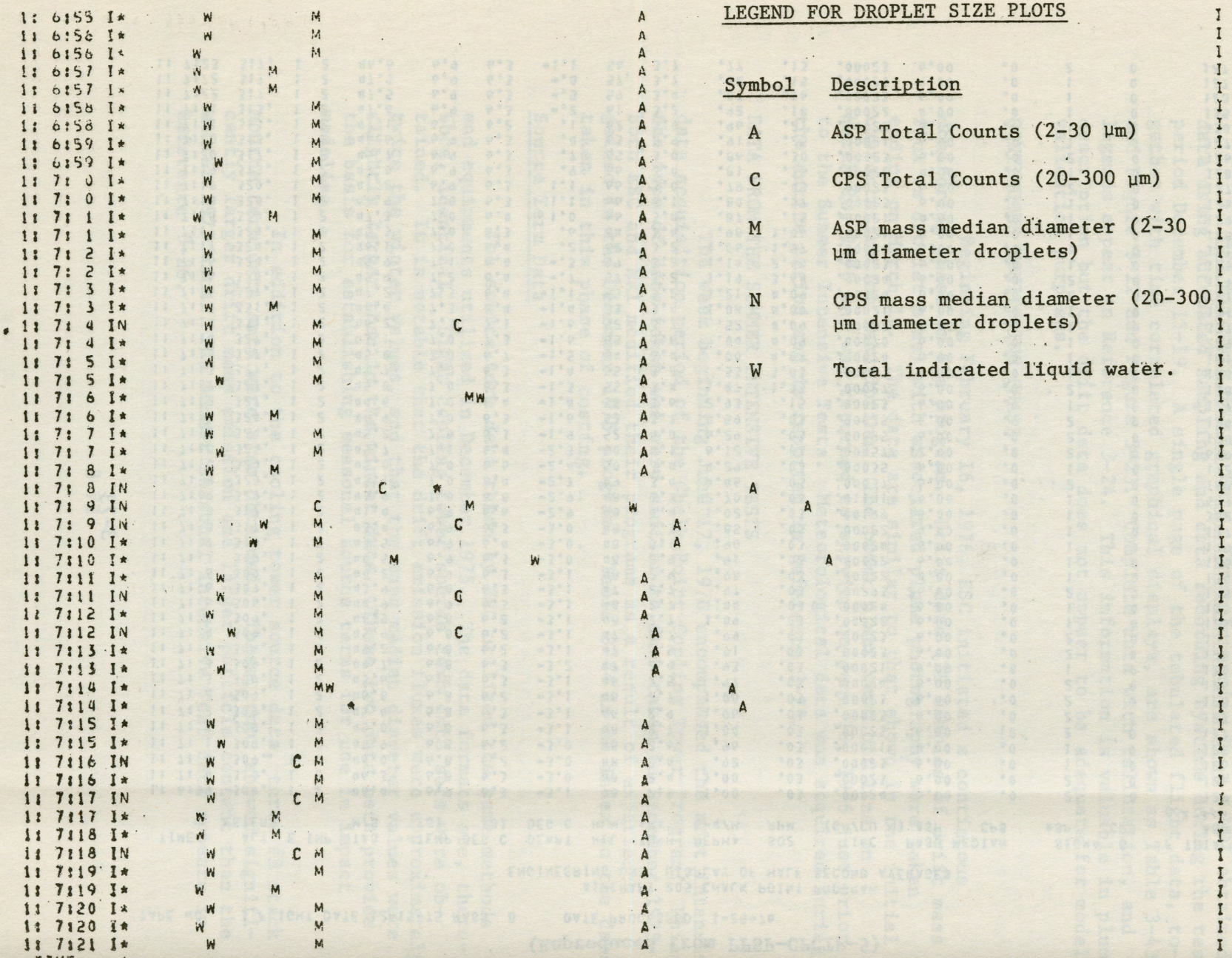
TAPE NO. 3 FLIGHT DATE 12-15-75 PASS 8 DATE PROCESSED 1-25-76

AIRCRAFT 205 CHALK POINT PROGRAM
ENGINEERING UNIT DISPLAY OF HALF SECOND AVERAGES

TIME	ALT METERS	E	IMP	TAS M/S	TEMP DEG C YSI	TSI	DEWPT DEG C	REL HUM	TURB *R*	NEPH* E-4/M	SO2 PPM	TIWC (GM/CU M)	MASS MEDIAN ASP	CPS	SIGMA G ASP	CPS	F TOTAL COUNTS ASP 2-3μm	CPS 20-30μm
1: 6:59	309.	1	2	46.4	6.9	6.3	-3.1	48	2.5	1.00	.03	.00024	6.00	.0	2	0	129	0
1: 7: 0	313.	1	2	46.3	6.8	6.3	-3.0	48	2.4	1.00	.03	.00023	6.00	.0	2	0	126	0
1: 7: 0	309.	1	2	46.0	6.8	6.2	-3.0	48	2.4	.92	.03	.00023	6.00	.0	1	0	126	0
1: 7: 1	309.	1	2	45.9	6.8	6.2	-3.0	48	2.6	.96	.03	.00021	4.00	.0	1	0	126	0
1: 7: 1	309.	1	2	45.0	6.8	6.3	-3.1	48	2.7	1.04	.03	.00023	6.00	.0	2	0	127	0
1: 7: 2	309.	1	2	45.4	6.8	6.3	-3.1	48	2.9	1.06	.03	.00023	6.00	.0	2	0	127	0
1: 7: 2	309.	1	2	46.8	6.8	6.2	-3.1	48	2.7	1.00	.03	.00023	6.00	.0	2	0	128	0
1: 7: 3	309.	1	2	45.6	6.8	6.3	-3.1	48	2.5	.97	.03	.00024	6.00	.0	2	0	126	0
1: 7: 3	309.	1	2	44.7	6.8	6.3	-3.2	47	2.4	.93	.03	.00021	4.00	.0	1	0	130	0
1: 7: 4	306.	1	2	45.2	6.8	6.2	-3.1	47	2.5	.91	.03	.00023	6.00	.0	2	0	126	22
1: 7: 4	309.	1	2	45.9	6.8	6.2	-3.1	47	2.7	.99	.03	.00023	6.00	.0	2	0	123	0
1: 7: 5	309.	1	2	46.5	6.8	6.2	-3.1	48	2.7	1.09	.03	.00022	6.00	.0	1	0	126	0
1: 7: 5	306.	1	2	44.9	6.9	6.3	-3.1	48	2.7	1.04	.03	.00024	6.00	.0	1	0	130	0
1: 7: 6	309.	1	2	43.9	6.8	6.3	-3.1	47	2.7	.97	.03	.00293	26.00	.0	2	0	135	0
1: 7: 6	309.	1	2	44.2	6.9	6.3	-3.1	48	2.9	.98	.03	.00022	4.00	.0	1	0	134	0
1: 7: 7	309.	1	2	44.5	6.9	6.3	-3.0	48	2.9	.91	.03	.00022	6.00	.0	1	0	125	0
1: 7: 7	313.	1	2	43.5	6.9	6.4	-3.0	48	3.1	.90	.03	.00024	6.00	.0	1	0	130	0
1: 7: 8	317.	1	2	43.4	6.9	6.3	-3.0	48	3.3	.85	.03	.00022	4.00	.0	1	0	127	0
1: 7: 8	317.	1	2	41.4	6.9	6.6	-2.9	48	3.4	1.02	.03	.00199	18.00	.0	1	0	362	11
1: 7: 9	320.	1	2	43.9	7.0	6.8	-2.9	48	3.7	2.70	.03	.01141	26.00	.0	1	0	597	6
1: 7: 9	320.	1	2	45.1	7.0	6.4	-2.7	49	3.4	4.46	.03	.00037	6.00	.0	2	0	168	22
1: 7:10	324.	1	2	45.0	7.0	6.6	-2.4	50	3.4	4.29	.03	.00035	6.00	.0	1	0	172	0
1: 7:10	324.	1	2	45.7	7.1	6.4	-2.3	50	4.1	6.12	.03	.00457	12.00	.0	2	0	699	0
1: 7:11	324.	1	2	45.2	7.0	6.3	-1.9	52	4.0	6.29	.03	.00025	6.00	.0	2	0	129	0
1: 7:11	324.	1	2	44.9	7.0	6.3	-1.6	53	3.7	4.59	.03	.00025	6.00	.0	2	0	129	22
1: 7:12	327.	1	2	44.6	7.0	6.4	-1.4	55	3.6	2.93	.15	.00023	6.00	.0	1	0	127	0
1: 7:12	327.	1	2	45.0	7.0	6.3	-1.3	55	3.4	1.47	1.33	.00027	6.00	.0	2	0	138	22
1: 7:13	327.	1	2	45.7	7.0	6.3	-1.4	55	3.2	.33	3.83	.00023	6.00	.0	1	0	138	0
1: 7:13	327.	1	2	45.4	7.0	6.7	-1.5	54	3.4	.00	4.09	.00024	6.00	.0	1	0	141	0
1: 7:14	327.	1	2	43.1	7.0	7.3	-1.6	53	3.6	.04	4.09	.00070	6.00	.0	1	0	289	0
1: 7:14	331.	1	2	46.2	7.3	7.1	-1.6	52	3.7	.52	4.09	.00082	8.00	.0	1	0	327	0
1: 7:15	331.	1	2	48.4	7.3	6.4	-1.4	53	3.4	1.08	4.09	.00021	6.00	.0	1	0	131	0
1: 7:15	327.	1	2	47.2	7.3	6.4	-1.1	55	3.2	1.21	4.09	.00024	6.00	.0	2	0	127	0
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1: 7:17	324.	1	2	46.1	7.0	6.4	.2	62	3.2	1.06	1.57	.00023	6.00	.0	1	0	131	5
1: 7:17	324.	1	2	45.3	7.0	6.3	.6	64	3.4	.98	1.06	.00021	4.00	.0	1	0	128	0
1: 7:18	324.	1	2	47.3	7.0	6.4	1.0	66	3.4	.87	.75	.00021	4.00	.0	1	0	129	0
1: 7:18	320.	1	2	47.9	7.0	6.3	1.1	66	3.1	.80	.57	.00023	6.00	.0	1	0	126	5
1: 7:19	320.	1	2	47.2	6.9	6.3	1.1	66	3.0	.79	.45	.00023	6.00	.0	2	0	127	0
1: 7:19	313.	1	2	47.0	6.9	6.3	.9	66	3.0	.81	.36	.00020	4.00	.0	1	0	128	0
1: 7:20	317.	1	2	46.7	6.9	6.3	.7	65	3.0	.86	.30	.00023	6.00	.0	2	0	126	0
1: 7:20	313.	1	2	46.6	6.9	6.3	.4	63	2.9	.91	.25	.00021	6.00	.0	1	0	127	0
1: 7:21	313.	1	2	47.1	6.9	6.2	.1	62	3.0	.96	.21	.00022	6.00	.0	1	0	130	0
1: 7:21	313.	1	2	47.8	6.9	6.3	-.2	61	3.2	.92	.18	.00022	4.00	.0	1	0	135	0
1: 7:22	317.	1	2	47.5	6.9	6.3	-.5	59	3.4	.87	.16	.00023	6.00	.0	1	0	128	0
1: 7:22	317.	1	2	47.5	6.9	6.3	-.8	57	3.7	.82	.15	.00021	4.00	.0	1	0	127	0
1: 7:23	317.	1	2	46.6	6.9	6.3	-1.1	56	3.7	.77	.13	.00023	6.00	.0	2	0	127	0

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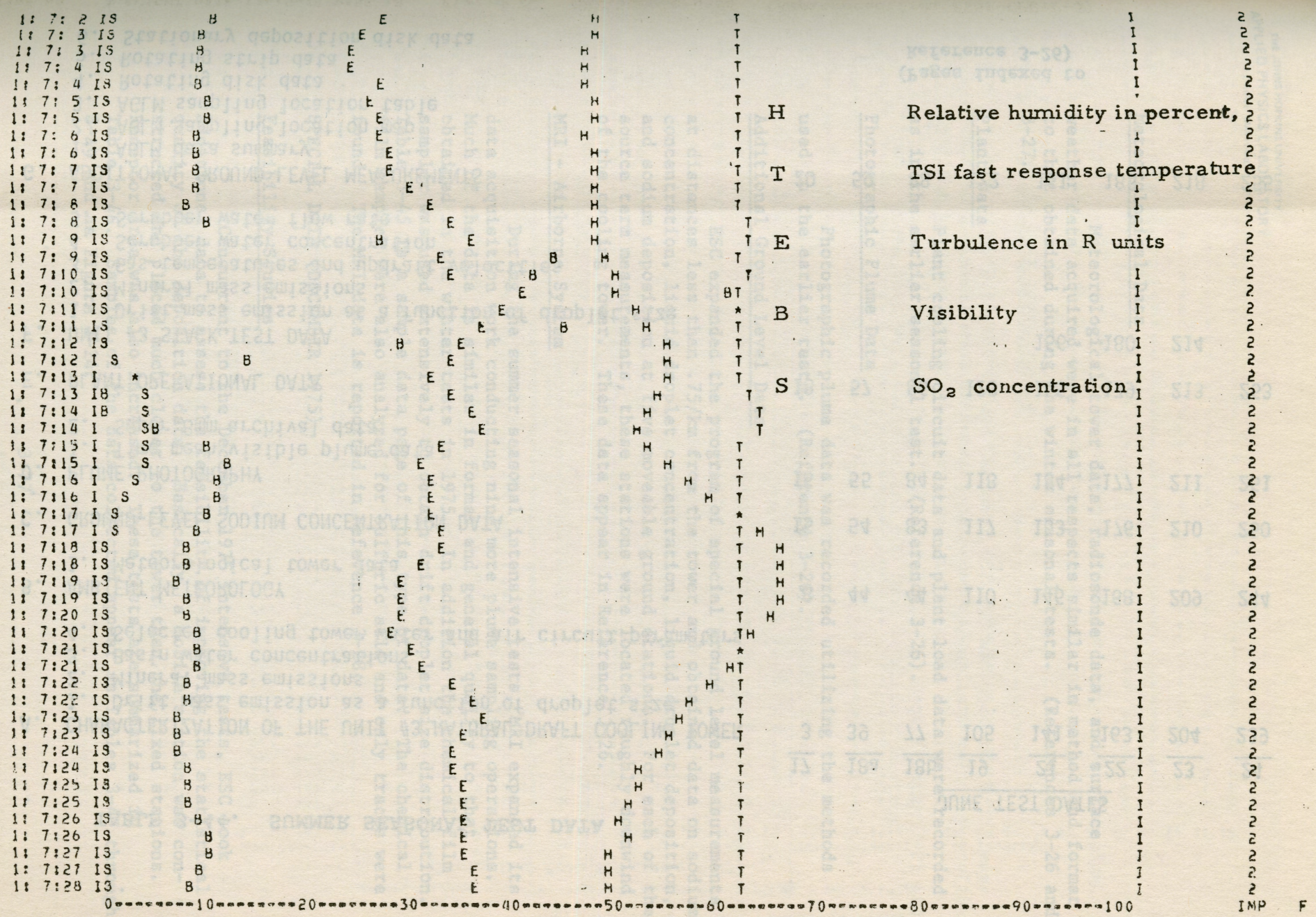
LEGEND FOR DROPLET SIZE PLOTS

Symbol	Description
A	ASP Total Counts (2-30 μm)
C	CPS Total Counts (20-300 μm)
M	ASP mass median diameter (2-30 μm diameter droplets)
N	CPS mass median diameter (20-300 μm diameter droplets)
W	Total indicated liquid water.

TAPE NO. 3 FLIGHT DATE 12-15-75 PASS 8 Fig. 3-22. MRI Sample Data (Reproduced from PPSP-CPCTP-5)

FLIGHT ALTITUDE 333 METERS MSL

TAPE NO. 3 FLIGHT DATE 12-15-75 PASS 8 Fig. 3-22. MRI Sample Data (Reproduced from PPSP-CPCTP-5)
FLIGHT ALTITUDE 313. METERS MSL



TAPE NO. 3 FLIGHT DATE 12-15-75 PASS 8
FLIGHT ALTITUDE 276. METERS MSL

Fig. 3-23. MRI Sample Plot (Reproduced from PPSP-CPCTP-5)

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TABLE 3-44. SUMMER SEASONAL TEST DATA

	JUNE TEST DATES							
	17	18a	18b	19	21	22	23	24
A. CHARACTERIZATION OF THE UNIT #3 NATURAL DRAFT COOLING TOWER	3	39	77	105	141	163	204	239
1. Drift mass emission as a function of droplet size								
2. Mineral mass emissions								
3. Basin water concentrations								
4. Selected cooling tower water and air circuit parameters								
B. AMBIENT METEOROLOGY	8	44	44	110	146	168	209	244
1. Meteorological tower data								
C. GROUND-LEVEL SODIUM CONCENTRATION DATA	15	54	83	117	153	176	210	250
D. PLUME PHOTOGRAPHY	16	55	84	118	154	177	211	251
1. Time mean visible plume data								
2. Super 8mm archival data								
E. PLANT OPERATIONAL DATA	18	57	86	120	155	179	213	253
F. UNIT #3 STACK TEST DATA					156	180	214	
1. Drift mass emission as a function of droplet size								
2. Mineral mass emissions								
3. Gas temperatures and updraft velocities								
4. Scrubber water concentration								
5. Scrubber water flow rate								
G. ADDITIONAL GROUND-LEVEL MEASUREMENTS	20	59	88	122	161	185	218	255
1. AGLM data summary								
2. AGLM sampling location map								
3. AGLM sampling location table								
4. Rotating disk data								
5. Rotating strip data								
6. Stationary deposition disk data								

(Pages indexed to Reference 3-26)

Meteorological Data

Meteorological tower data, radiosonde data, and surface weather data acquired were in all respects similar in method and format to that obtained during the winter seasonal tests. (References 3-26 and 3-27.

Plant Data

Plant cooling circuit data and plant load data were recorded as in the earlier seasonal test. (Reference 3-26).

Photographic Plume Data

Photographic plume data was recorded utilizing the methods used in the earlier tests. (Reference 3-26).

Additional Ground Level Data

ESC expanded the program of special ground level measurements at distances less than .75/km from the tower and obtained data on sodium concentration, liquid droplet concentration, liquid droplet deposition, and sodium deposition at five moveable ground stations. For each of the source term measurements, these stations were located roughly downwind of the cooling tower. These data appear in Reference 3-26.

MRI - Airborne System

During the summer seasonal intensive tests, MRI expanded its data acquisition work conducting nine more plume sampling operations. Much of the data is similar in format and general quality to that obtained in the winter tests in 1975. In addition the chemical film sampler was used extensively to obtain drift droplet size distribution. Table 3-45 is a sample data page of this type of data. The chemical film samples were also analyzed for sulfuric acid and only traces were found. The MRI data is reported in Reference 3-28.

SPECIAL DATA (DECEMBER 1975)

Feasibility Studies

Concurrent to the December 1975 intensive tests, ESC took additional data to assess the feasibility of improving the statistical quality of the deposition data. Basically, a mobile station was constructed and placed much closer to the tower than the fixed stations. Receptor area was also increased. These tests are summarized in Table 3-46. Samples of the data collected appear as Tables 3-47 through 3-49 and as Figure 3-24.

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Table 3-45. Sample Data Sheet (MRI - Sensitive Film)

CHALK POINT SALT DRIFT DROPLET SIZE DISTRIBUTIONS - JUNE, 1976

(Reproduced from Reference 3-33)

TRAVERSE NUMBER	MASS (GRAMS)	MASS DIAMETERS MEDIAN	16%	84%	NUMBER OF DROPLETS PER 14 MICRON DIAMETER SIZE INCREMENT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
8: 1	.704E-04	441	147	441	6	3	3	5	1	4	3	3	4	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8: 2-3	.308E-03	357	189	441	28	10	9	9	12	11	5	6	4	5	12	2	0	2	2	1	2	0	2	2	0	1	0	0	1	1	0	0	0	0	1	2
8: 4	.393E-05	133	105	147	7	3	2	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8: 5	.137E-04	245	147	245	15	1	2	0	1	2	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8: 6-8	.603E-03	427	315	441	43	7	4	5	4	5	2	4	0	7	0	3	1	2	0	2	0	0	0	0	2	0	2	1	2	0	1	0	1	2	1	6
8: 9-44*	.109E-03	441	329	441	7	8	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
8:45	.276E-04	245	203	245	2	1	3	1	2	2	4	0	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8:46	.248E-04	259	133	273	8	2	2	3	2	2	4	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8:47	.529E-04	231	147	273	7	4	2	2	4	2	6	1	3	1	1	1	0	1	1	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
8:48	.786E-04	441	189	441	1	2	4	3	0	3	4	0	2	2	0	1	1	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8:49	.379E-03	273	189	413	13	9	18	13	13	12	14	10	11	4	8	2	2	5	4	3	2	4	1	3	3	0	0	1	0	1	1	0	0	1	0	1
8:50-55	.132E-02	441	315	441	51	14	10	12	12	15	9	11	8	9	6	5	3	5	4	3	1	2	0	1	3	1	2	2	1	0	1	0	1	1	2	19
8:56-70*	.483E-03	441	287	441	124	16	6	2	3	2	5	2	1	3	2	0	3	0	1	2	0	3	0	1	2	0	0	0	1	1	0	0	0	0	0	7
8: **	.666E-04	245	175	329	17	4	4	2	5	3	2	4	2	0	2	0	1	1	1	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
8:71	.184E-03	329	175	441	33	2	3	3	4	5	6	3	2	5	6	2	4	0	1	0	2	1	0	1	0	0	0	1	0	0	0	0	0	0	0	2
8:72	.957E-04	301	175	441	75	6	4	3	5	6	3	1	1	2	2	0	3	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
8:73	.932E-04	287	175	441	23	1	4	3	4	4	5	4	1	0	2	2	2	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
8:74	.193E-04	175	161	203	13	3	1	1	2	0	1	0	0	1	0	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8:75	.130E-03	441	259	441	29	2	2	1	0	2	2	3	1	0	0	1	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	2
8:76-77	.263E-03	441	189	441	79	13	5	6	9	8	11	3	4	5	4	3	1	3	1	1	2	2	0	1	0	0	0	0	0	0	0	0	0	1	0	3
10: 1	.197E-04	301	147	301	24	6	1	5	1	0	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
10: 2	.896E-04	189	119	245	18	16	9	8	13	10	10	7	6	2	4	3	0	4	0	1	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
10: 3	.329E-03	441	161	441	15	22	33	21	27	3	5	11	5	9	6	6	5	4	3	2	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	4
10: 4	.147E-05	133	77	133	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10: 5	.447E-06	63	49	63	1	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10: 6	.439E-05	189	91	189	6	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10: 7	.175E-05	91	63	105	6	2	5	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10: 8	.221E-03	441	175	441	25	19	32	29	15	21	16	7	4	4	4	0	4	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	3
10: 9	.360E-03	315	161	441	63	23	28	26	18	16	16	5	9	11	6	4	4	1	3	1	1	2	0	1	1	3	1	0	0	0	1	0	0	0	0	3
10:10	.154E-03	315	147	441	16	15	26	21	18	13	7	7	4	5	3	4	1	0	0	2	2	1	0	0	0	0	1	0	1	0	0	0	0	0	0	3
10:11	.223E-03	259	175	441	76	24	22	18	16	11	6	7	5	7	2	0	5	2	4	3	2	1	2	1	0	1	0	0	0	0	0	1	0	0	0	1
10:12	.265E-03	217	119	441	44	40	57	44	49	41	29	17	12	12	8	7	5	4	1	2	2	0	1	0	0	1	0	0	1	1	0	0	0	0	0	1
11: 2	.190E-03	259	161	441	37	19	10	10	10	11	8	6	5	7	3	2	5	1	1	3	1	2	1	0	0	0	0	1	0	1	0	0	0	0	0	1
11: 3	.332E-04	203	161	259	9	2	1	1	2	0	2	0	0	1	1	1	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11: 4	.536E-04	203	133	329	1	0	3	2	5	4	4	5	2	2	2	1	2	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
11: 5	.787E-05	231	105	231	36	3	0	0	0	0	2	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11: 6	.662E-05	203	147	203	4	0	0	3	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11: 7-12	.449E-03	357	203	413	19	4	10	7	7	8	5	10	6	7	7	6	4	1	2	3	1	1	1	0	2	2	1	2	0	1	1	1	2	1	0	1
11:13-18	.029E-03	371	189	441	18	3	8	9	7	10	8	7	7	8	3	8	5	3	5	3	2	1	1	1	2	1	1	0	0	0	1	2	0	0	0	3
11:19-30	.735E-03	427	259	441	12	1	7	8	5	0	4	10	7	4	2	5	3	4	3	0	2	1	3	1	0	1	2	1	1	1	0	1	2	0	1	8
11:31	.382E-03	371	189	441	6	0	5	5	10	10	6	6	12	5	3	2	3	5	6	1	1	0	0	1	2	0	1	0	0	1	2	1	1	0	0	2
11:32	.791E-05	217	147	217	2	0	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11:33	.872E-06	105	63	105	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11:34	.219E-05	161	161	161	5	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11:35	.149E-04	189	189	231	0	0	1	1	1	1	0	0	1	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11:36-42	.154E-03	301	189	399	4	1	4	3	4	1	3	5	2	0	2	3	3	4	2	2	0	0	0	0	1	1	0	1	0	0	1	0	1	0	0	0
11:43-51	.816E-03	427	287	441	15	7	5	8	8	7	7	5	3	5	2	3	3	4	3	4	2	1	0	2	1	1	2	1	1	2	1	0	1	1	1	9
11:52-60	.468E-03	441	217	441	8	3	1	5	6	6	4	7	4	2	3	2	3	8	3	3	1	1	1	1	0	2	1	0	0	0	1	0	0	0	0	6
12: 1	.170E-04	175	133	231	17	2	0	0	1	1	2	0	1	1	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12: 1-5	.486E-04	441	441	441	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12: 6-10	.952E-04	441	441	441	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12:11-15	.157E-04	189	189	231	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

* Questionable data, large samples gave droplet overlap

** In plume but not of traverse sampling

Source Term Data

APL requested ESC to record droplet number vs droplet size. This was done during the intensive tests and appears as Table 3-50.

Stack #3 Salt Measurements

On December 17 and December 18, ESC measured the drift mass emission, mineral mass emissions, temperature, updraft velocity profiles, and the scrubber water concentrations of Stack #3. Data from the December 17, 1975 tests are attached as Table 3-51 and Figures 3-25 and 3-26. These data were taken at the 400 foot level in the stack.

Table 3-46. Additional Ground-Level Measurements (Feasibility Study) Summary for 12-19-75 *

Parameter Measured	Measurement Technique	Location	Time EST	Volume Sampled (m^3)	Collection		Output
					(Net µg Na)		(µg Na/m^3)
Mineral Mass Concentration in the air	Airborne Particle Sampler	1NE	10:45-15:57	112.4	0.9		0.008
		1S	9:10-13:47	66.9	0.6		0.009
		1E	10:07-15:17	114.2	1.1		0.010
		1SE	9:50-14:58	114.1	1.7		0.015
		2SE	9:37-14:45	113.2	1.7		0.015
		ME	9:09-14:20	110.5	2.75		0.025
	Cascade Impactor	ME	10:32-14:50	219.2	20.4		0.09
				Area (cm^2)			(Kg Na/Km^2-mo)
Mineral Mass Deposition Flux	Funnel and Bottle Assembly	ME	9:09-14:20	324.3	48.8		216.12
					# Droplets	µg liquid	(µg liquid/m^3)
Liquid Droplet Concentration in the air	Sensitive Paper Strip	ME	9:09-14:20	22.2	47	405.6	18.27
				Area (cm^2)	# Droplets	µg liquid	(Kg liquid/Km^2-mo)
Liquid Droplet Deposition Flux	Sensitive Paper Disc	ME	9:09-14:20	9	10	See footnote[1]	See footnote[1]

[1] Some large stains (e.g. corresponding to droplets around 1800µm) were noted. There is a question as to the origin of these stains and therefore no values are included here.

*Reproduced from PPSP-CPCTP-8

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Table 3-47. Water Deposition Flux as a Function of Droplet Size (Reproduced from PPSP-CPCTP-8)

Date and Time: December 19, 1975, 9:09 - 14:20 EST
Measurement Location: Mobile Station East (ME), see Appendix I
Measurement Technique: Sensitive Paper Disc

I	d' μm	d" μm	Δd μm	d_c μm	# droplets	Deposition Flux kg/km²/mo.
1	~2.0	10.2	8.2	6.1	3	0.055
7	61.2	71.4	10.2	66.3	2	47.0
8	71.4	81.6	10.2	76.5	1	36.2
9	81.6	91.8	10.2	86.7	1	52.66
28	275.4	285.6	10.2	280.5	1	1783.3
51	510.0	520.2	10.2	515.1	1	11043.
184[1]	1866.6	1876.8	10.2	1871.7	1	529,825

[1] The origin of a droplet of this size is questionable.

Sodium Concentration

Date: December 19, 1975
Measurement Technique: Airborne Particle Sampler (APS)

Station[1]	Sodium Concentration (μg/m³)	Run Time Start/End EST	Volume Sampled (m³)	Net Na Collected (μg)
ME	0.025	9:09/14:20	110.54	2.75

Sodium Deposition Flux

Date: December 19, 1975
Measurement Technique: Deposition Funnel and Bottle Assembly

Station[1]	Sodium Deposition Flux (kg/km²/mo.)	Run Time Start/End EST	Exposed Area	Net Na Collected (μg)
ME	216.12	9:09/14:20	324.3	48.8

[1] For Station Location, See Appendix I.

Table 3-48. Additional Ground Level Measurements (Feasibility Study)

(Reproduced from PPSP-CPCTP-8)

Additional Ground Level Measurements (Feasibility Study)

a. Mass of Water per Unit Volume of Air as a Function of Droplet Size

Date and Time: December 19, 1975, 9:09 - 14:20 EST
Measurement Location: Mobile East (ME), See Appendix I.
Measurement Technique: Sensitive Paper Strip

I	d' (μm)	d" (μm)	Δd (μm)	# of Droplet Counts	ΔX (μg/m³)	ΔX/X (%)
1	10	50	40	29	0.022	0.12
2	50	100	50	7	0.0566	0.31
3	100	200	100	8	0.346	1.89
4	200	400	200	0	0	0
5	400	600	200	2	7.891	43.20
6	600	800	200	1	9.95	54.47
					X=ΣΔX = 18.266	99.99*

Note: The above droplet size ranges are approximate due to stain size grouping and stain size versus droplet size calibration.

* The sum differs from 100% due to rounding.

Table 3-49. Rotating Sensitive Paper Droplet Counts

(Reproduced from PPSP-CPCTP-8)

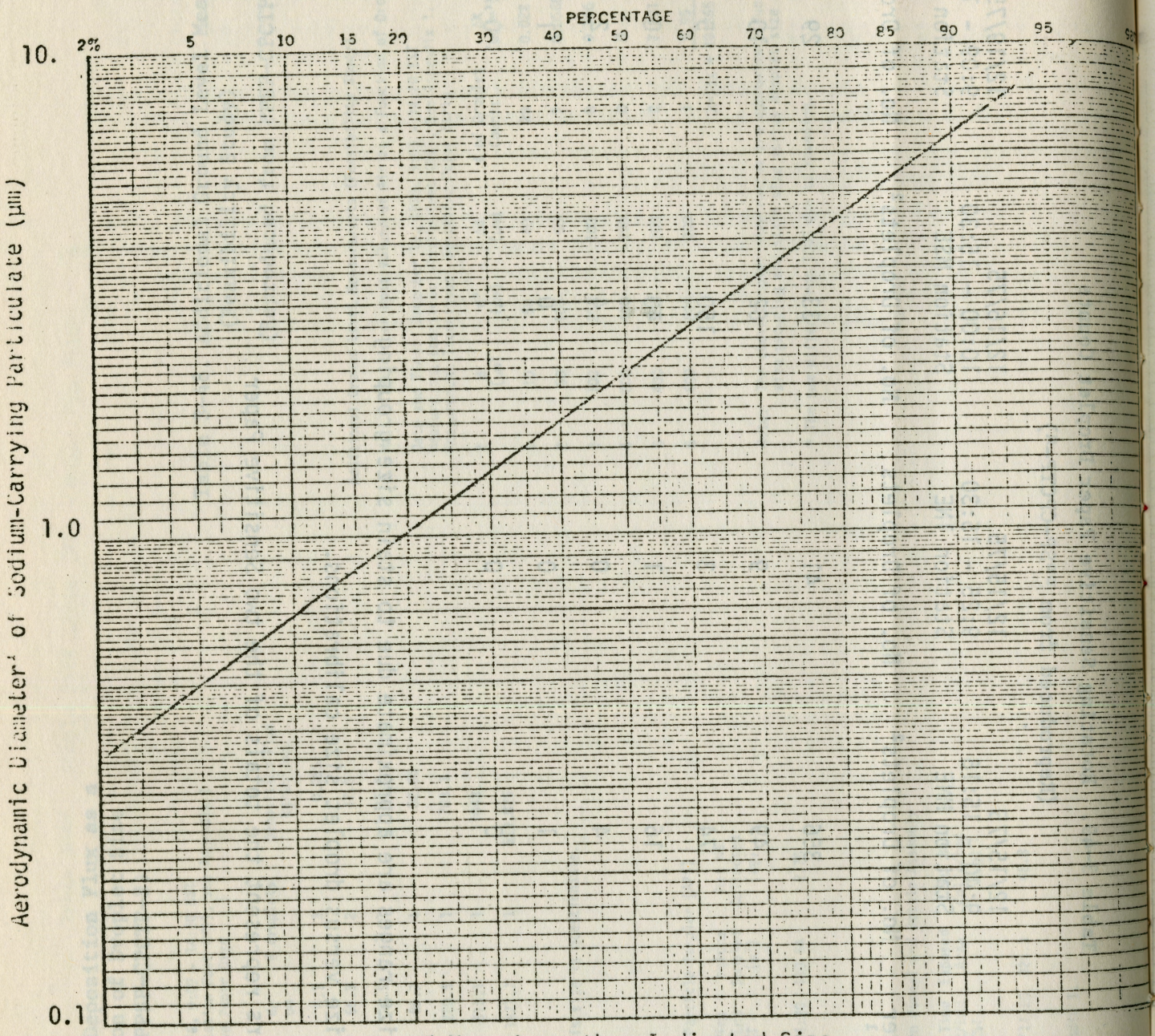
Droplet Diameter Interval (μm)[1]	12/15/75 9:40 - 15:16 Station MNE No. of Droplets[2]	12/15/75 9:25 - 15:30 Station 1NE No. of Droplets	12/16/75 10:00 - 15:30 Station MSE No. of Droplets[2]	12/19/75 9:09 - 14:20 Station ME No. of Droplets
10 - 50	356	41	33	29
50 - 100	49	9	62	10
100 - 200	74	3	150	5
200 - 400	16	1	40	0
400 - 600	4	0	4	2
600 - 800	1	0	0	1
800 - 1000	0	0	1	0

[1] The above size ranges are approximate due to stain size grouping and stain size versus droplet size calibrations.

[2] These numbers represent the totals of the two Sensitive Paper strips runs.

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Date and Time: December 19, 1975, 10:32 - 14:52 EST
Measurement Location: Mobile Station East (ME), See Appendix I
Measurement Technique: Cascade Impactor



Mass Median Diameter = 2.16 μm
Standard Deviation = 1.56

[1] Aerodynamic Diameter assumes spherical particles of unit density.

Figure 3-24. Aerodynamic Size Distribution of Sodium Carrying Particulate (Reproduced from PPSP-CPCTP-8)

Table 3-50. Cooling Tower Drift Droplet Counts
(Reproduced from PPSP-CPCTP-8)

Measurement Mode: Equal Area Traverse
Measurement Location: North-South Diameter, Upper Level
These Data were Acquried by: Pills and SP

The droplet number counts at the large droplet end of the droplet spectrum are given in the table below to indicate the statistical base of the droplet emission data. For the small droplet range, only one typical example of the number of counts is given.

The droplet size ranges are approximate due to droplet size grouping.

d' μm	d" μm	Δd μm	12-15-75 9:40-15:23	12-16-75 11:56-15:26	12-17-75 9:05-12:47	12-17-75 15:35-17:19	12-18-75 8:31-12:15 EST
10	40	30			1226[1]		
40	70	30			378[1]		
70	100	30			206		
100	130	30			77		
130	160	30			436[2]		
160	190	30			178		
190	220	30			76		
220	270	50			40		
270	320	50	19	10	18	14	17
320	400	80	17	7	23	12	28
400	500	100	15	5	12	9	16
500	600	100	8	1	8	4	6
600	800	200	3	2	5	5	7
800	1000	200	2	0	2	2	4
1000	1400	400		3	4		7
1400	1800	400		3			3

Footnote [1]: SP counts only, PILLS data omitted due to large contribution of noise counts resulting from fog background fluctuations.

Footnote [2]: A larger portion of the SP area is analyzed for droplet diameters larger than 130μm which results in larger counts above that diameter.

Table 3-51. Unit #3 Stack Test Data
(Reproduced from PPSP-CPCTP-8)

Drift Mass Emission at the 420 Foot Level as a Function of Droplet Size.

Date and Time: December 17, 1975, 21:00 - 22:00 EST
Measurement Mode: Equal Area Traverse (along two perpendicular diameters)
Stack Cross-Sectional Area at the Measurement Location: 45.6m²
This Data was Acquired by: SP

I	d'	d"	Δd	d_c	ΔD	ΔD/D
	μm	μm	μm	μm	gm/s	%
1	10	30	20	20	0.347	25.8
2	30	50	20	40	0.110	8.2
3	50	70	20	60	0.129	9.6
4	70	90	20	80	0.137	10.2
5	90	110	20	100	0.133	9.9
6	110	130	20	120	0.121	9.0
7	130	150	20	140	0.100	7.4
8	150	180	30	165	0.118	8.8
9	180	210	30	195	0.078	5.8
10	210	240	30	225	0.044	3.3
11	240	270	30	255	0.027	2.0
					D = ΣΔD = 1.345	100.0

Mass Median Diameter: 82μm

Mineral Mass Emissions at the 420 Foot Level.

Date and Time: December 17, 1975, 15:20 - 20:25 EST
Measurement Mode as Above
Data was Acquired by: IK

Sodium emission: 1.17 gm/s
Magnesium emission: 0.48 gm/s

Gas Temperatures and Updraft Velocities at the 420 Foot Level.

The following data are averaged over the time period of the IK Equal Area Traverse:

Dry bulb temperature: 58°C, standard deviation: 2.1°C
Updraft velocity: 15.1 m/s, " " not measured

Scrubber Water Concentrations

Sodium concentrations: 3680 mg/liter, NE Valve
3940 mg/liter, SE Valve

Magnesium concentrations: 1028 mg/liter, NE Valve
996 mg/liter, SE Valve

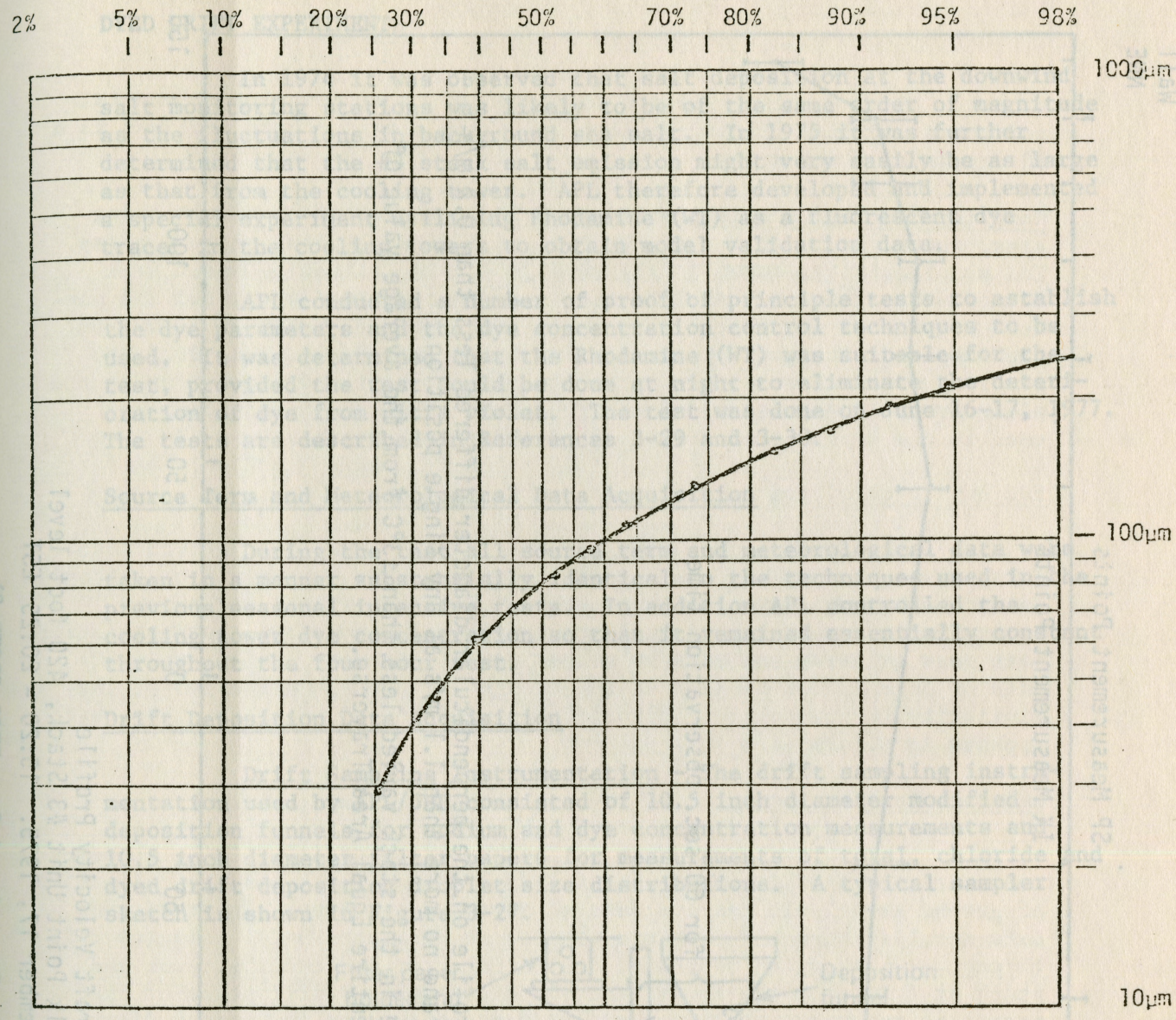


Fig. 3-25 Drift Mass Emission Fraction
Below Droplet Diameter Indicated
Chalk Point Unit #3 Stack
December 17, 1975. 21:00 - 22:00 EST
(Reproduced from PPSP-CPCPT-8)

Data points indicate mass fractions as calculated from the measured data. Data in Table F.1.a. were read from the solid line in this figure.

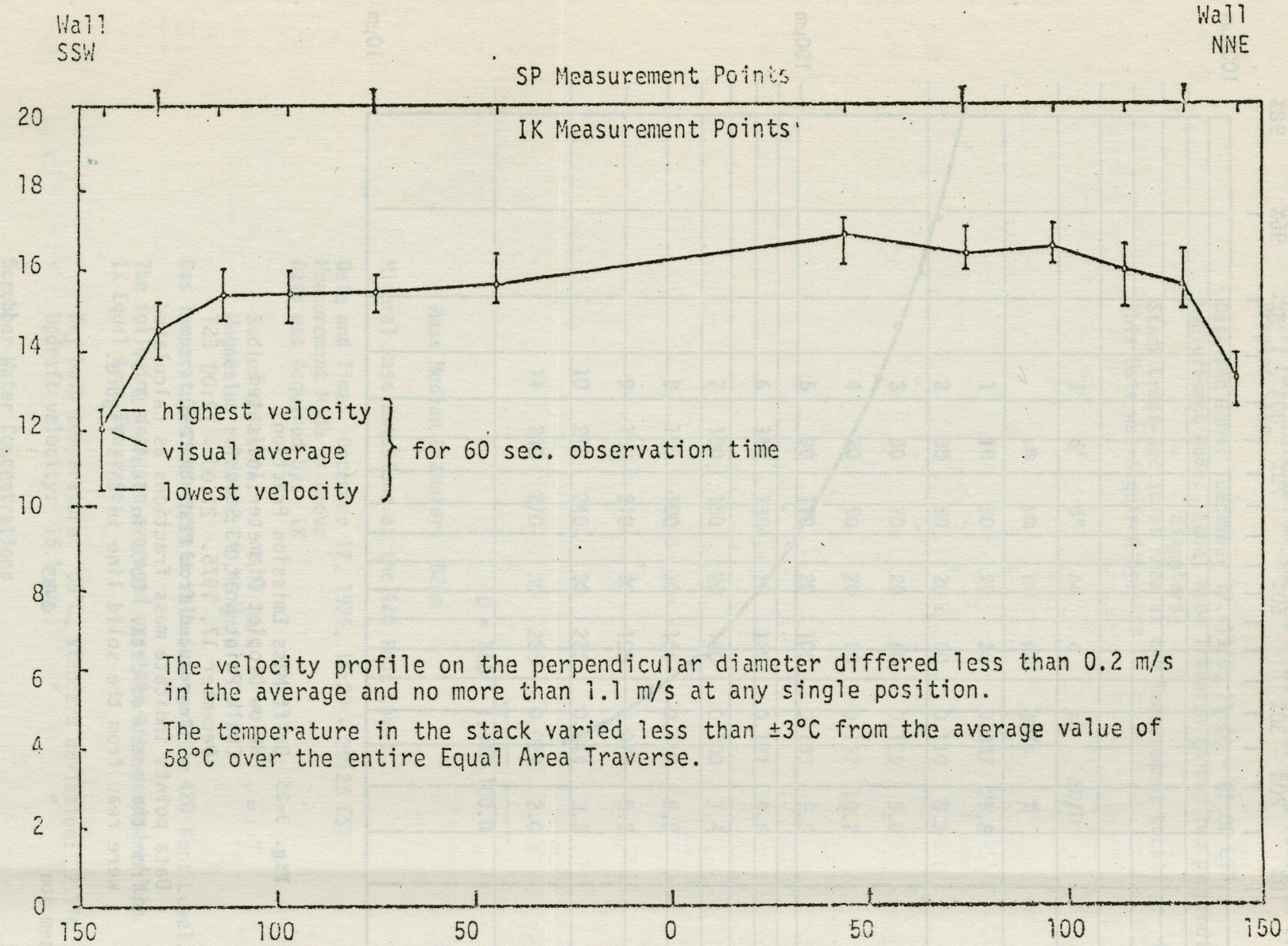


Fig. 3-26 Updraft Velocity Profile
Chalk Point Unit #3 Stack, 420 foot level
December 17, 1975. 15:20 - 20:25 EST

(Reproduced from PPSP-CPCTP-8)

(Reproduced from PPSP-CPCTP-8)

DYED DRIFT EXPERIMENT

In 1974 it was observed that salt deposition at the downwind salt monitoring stations was likely to be of the same order of magnitude as the fluctuations in background sea salt. In 1975 it was further determined that the #3 stack salt emission might very easily be as large as that from the cooling tower. APL therefore developed and implemented a special experiment utilizing Rhodamine (WT) as a fluorescent dye tracer in the cooling towers to obtain model validation data.

APL conducted a number of proof of principle tests to establish the dye parameters and the dye concentration control techniques to be used. It was determined that the Rhodamine (WT) was suitable for the test, provided the test could be done at night to eliminate the deterioration of dye from ultra violet. The test was done on June 16-17, 1977. The tests are described in References 3-29 and 3-30.

Source Term and Meteorological Data Acquisition

During the test all source term and meteorological data were taken in a manner substantially identical to the techniques used in the previous seasonal intensive tests. In addition APL controlled the cooling tower dye concentration so that it remained essentially constant throughout the four hour test.

Drift Deposition Data Acquisition

Drift Sampling Instrumentation - The drift sampling instrumentation used by APL/JHU consisted of 10.5 inch diameter modified deposition funnels for sodium and dye concentration measurements and 10.5 inch diameter filter papers for measurements of total, chloride and dyed drift deposition droplet size distributions. A typical sampler sketch is shown in Figure 3-27.

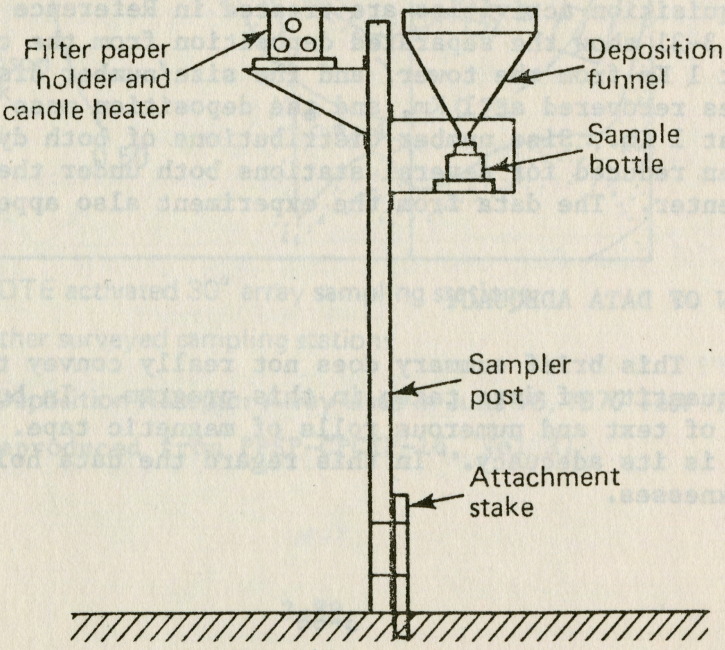


Fig. 3-27 Deposition and Dropsize Sampling Instrumentation

Each sampling station consisted of three deposition funnels, and three dropsize filter samplers and these stations were deployed in a 30 degree sampling array.

Sampling Station Locations - Figure 3-28, a sketch of the Chalk Point area, shows the locations of the 0.5 and 1.0 Km sampling station sites. The sampling sites shown in Figure 3-28 are identified by small dark diamond-shaped marks. At 1 Km the sites were located every two and one-half degrees of arc which is approximately every 43 meters. At 0.5 Km the sampling sites were located every 5 degrees of arc. The 0.25 Km sampling sites were selected prior to the dye test and located under the plume every 10 degrees or 43 meters apart. The data acquisition arc used in the test extended from 335 degrees to 5 degrees.

ESC Data Acquisition

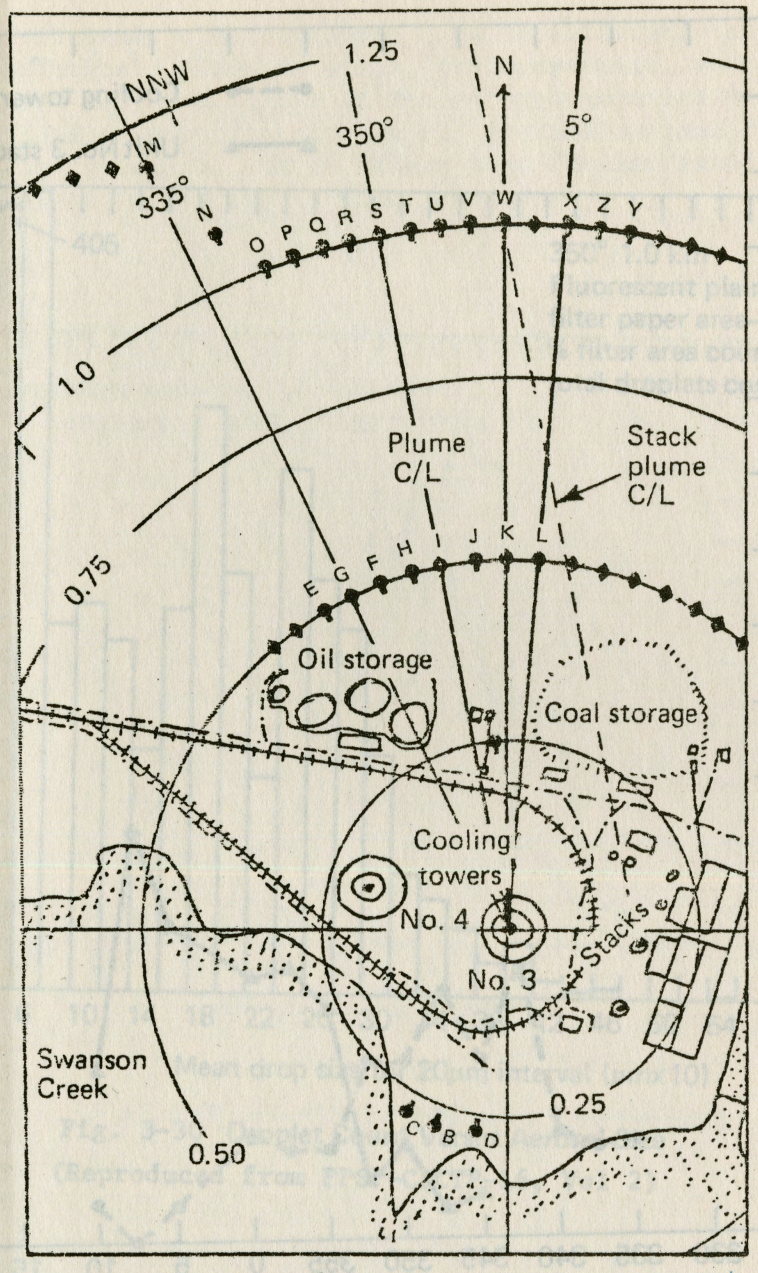
During this test, ESC acquired source term data, ground level data, plume photography, meteorological tower data, and plant operational data in a manner very similar to that of both the winter and summer intensive test periods reported previously. The emission characteristics, both mass emission and size vs number count, are very similar to the data of June 1977. Samples of these data are not shown because of the similarity to previously included data. All the ESC data for this test appears in Reference 3-30.

APL Data Acquisition

During this test, APL was responsible for maintaining the dye concentration in the tower, obtaining radiosonde data, and the collection of ground level salt and dye data at downwind stations. The test and data acquisition activities are treated in Reference 3-29. Figures 3-29 through 3-31 show the separated deposition from the cooling tower and stack at 1 Km from the tower, and the size/number distribution of dyed particles recovered at 1 Km, and the deposition mass for action distribution at 1 Km. Size number distributions of both dyed and total aerosol have been reduced for several stations both under the plume and off-plume center. The data from the experiment also appears in Reference 3-29.

A REVIEW OF DATA ADEQUACY

This brief summary does not really convey the proper concept of the quantity of data taken in this program. In bulk it fills many volumes of text and numerous rolls of magnetic tape. The real issue, of course, is its adequacy. In this regard the data hold both strengths and weaknesses.



● DDTE activated 30° array sampling stations

◆ Other surveyed sampling stations

Fig. 3-28 Deposition Receptor Array Used in June 16, 1977 Test
(Reproduced from PPSP-CPCTP-16, Vol 2)

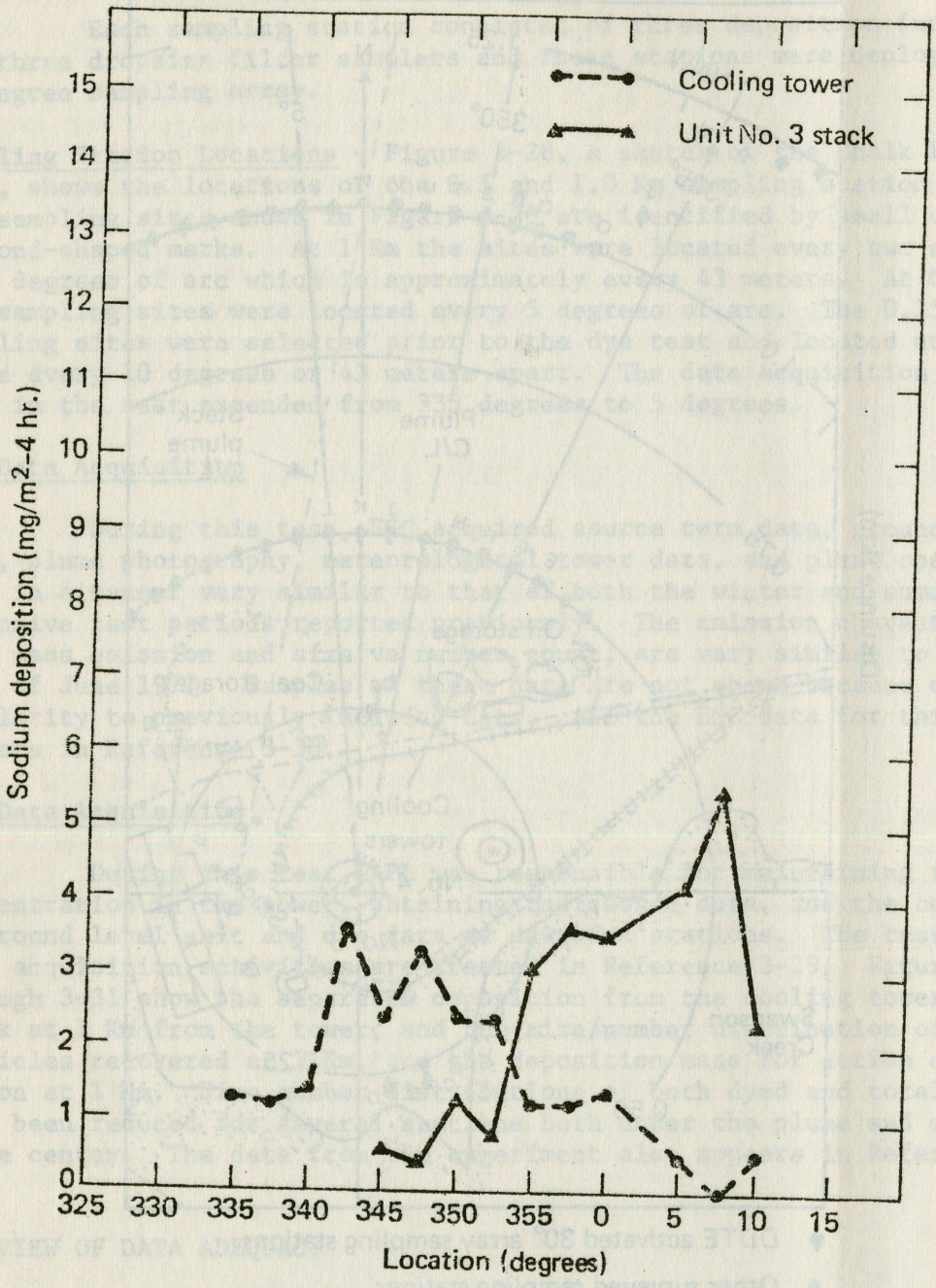


Fig. 3-29 . Calculated Sodium Deposition Rate from Major Chalk Point Sources 1.0 km

(Reproduced from PPSP-CPCTP-16, Vol 2)

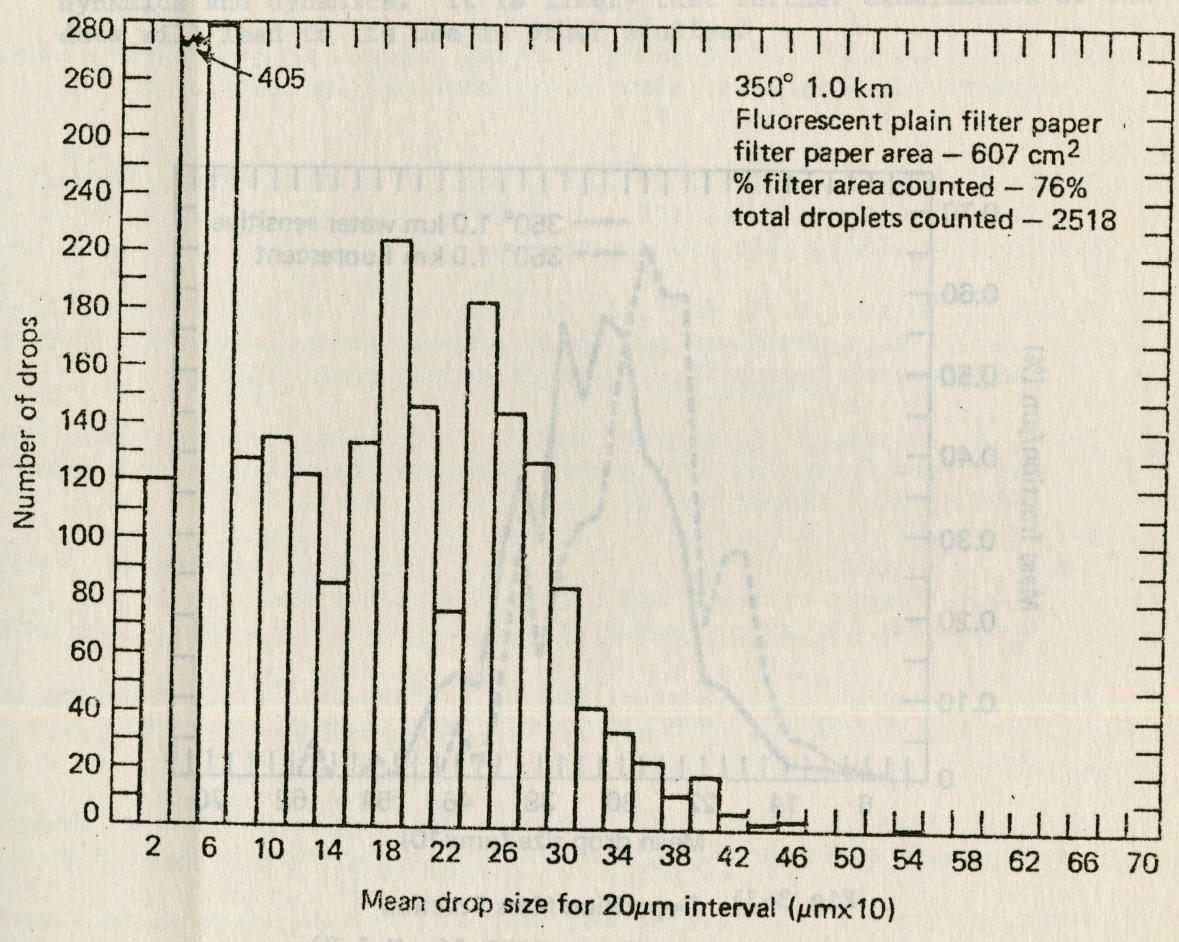


Fig. 3-30 Droplet Count Versus Aerosol Size
(Reproduced from PPSP-CPCTP-16, Vol 2)

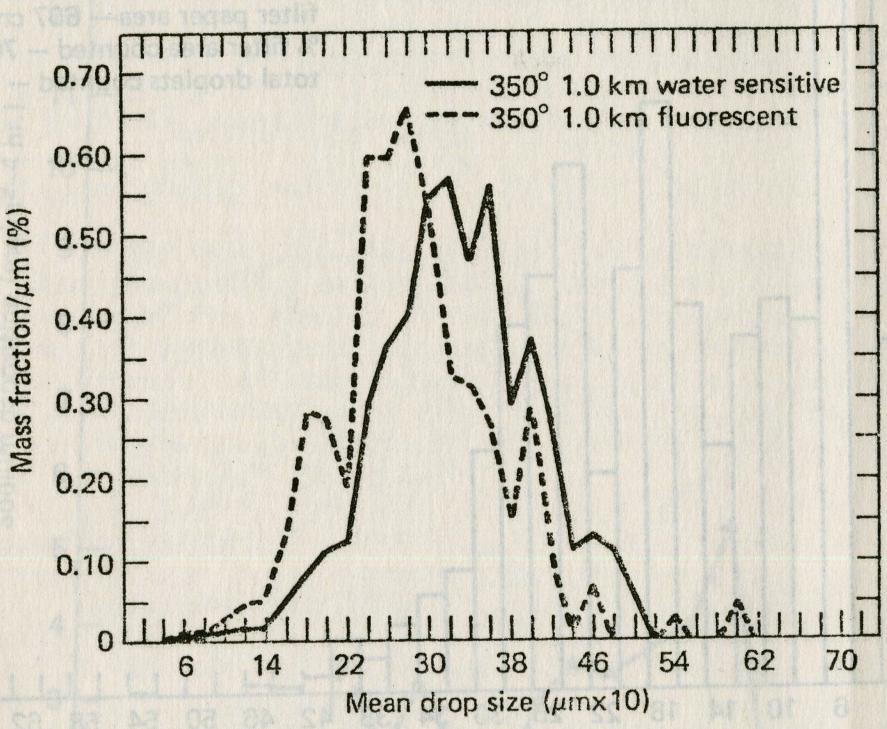


Fig 3-31 Deposition Mass Fraction

(Reproduced from PPSP-CPCTP-16, Vol 2)

It seems clear that the data contains many subsets which will be useful in basic plume dynamics, thermodynamics, and evaporation studies. In addition, there is much source term and meteorological data which will be valuable in studies of internal cooling tower thermodynamics and dynamics. It is likely that further examination of the data will lead to its use in other studies.

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CHAPTER IV

RESULTS AND CONCLUSIONS

SUMMARY OF RESULTS

Reference 4-1 sets forth the key results of the Chalk Point Cooling Tower Study in terms of expected environmental impacts. It is shown that the effects of the drift from the cooling tower (and stack) on soils and plant are expected to be very small. The conclusion is based on the results of test programs with plants and soils at the University of Maryland as supported by deposition modeling studies conducted at APL/JHU utilizing data from the sources enumerated in Chapter III. This work is summarized below. In addition various data analysis studies by ESC and MRI are described.

THE ESTIMATION OF SALT DEPOSITION

An estimation of the distribution of salt drift deposition from a cooling tower (or other source) is essential to the prediction of salt impact. Such an estimate is made by combining source term data, ambient meteorological data, and analytical drift transport deposition modeling. The available input data are described and referenced in Chapter III. The development, use and results of modeling are discussed here.

Model Description

The APL/JHU saline drift model has been developed, improved and validated to provide estimates of salt deposited on the ground around a cooling tower that uses saline cooling water. The model is structured for impact studies, i.e., to be used in conjunction with a large meteorological data base so that thousands of meteorological cases can be considered and the results tabulated as a function of range and direction from the tower. It incorporates the physical processes that are expected to make significant contributions to the amount and distribution of drift deposition and provides predictions that are in satisfactory agreement with available measurements of deposition. A graphic description of the modeling concept is shown in Fig. 4-1.

The Vapor Plume Sub-Model. The purpose of this sub-model is to predict the plume rise trajectory, the maximum rise height and the size of the moist buoyant plume emitted from the tower under various plant and ambient atmospheric conditions. In addition thermodynamic characteristis are estimated as the plume grows with the entrainment of ambient air. Details are given in Reference 4-2, 4-3, and 4-4.

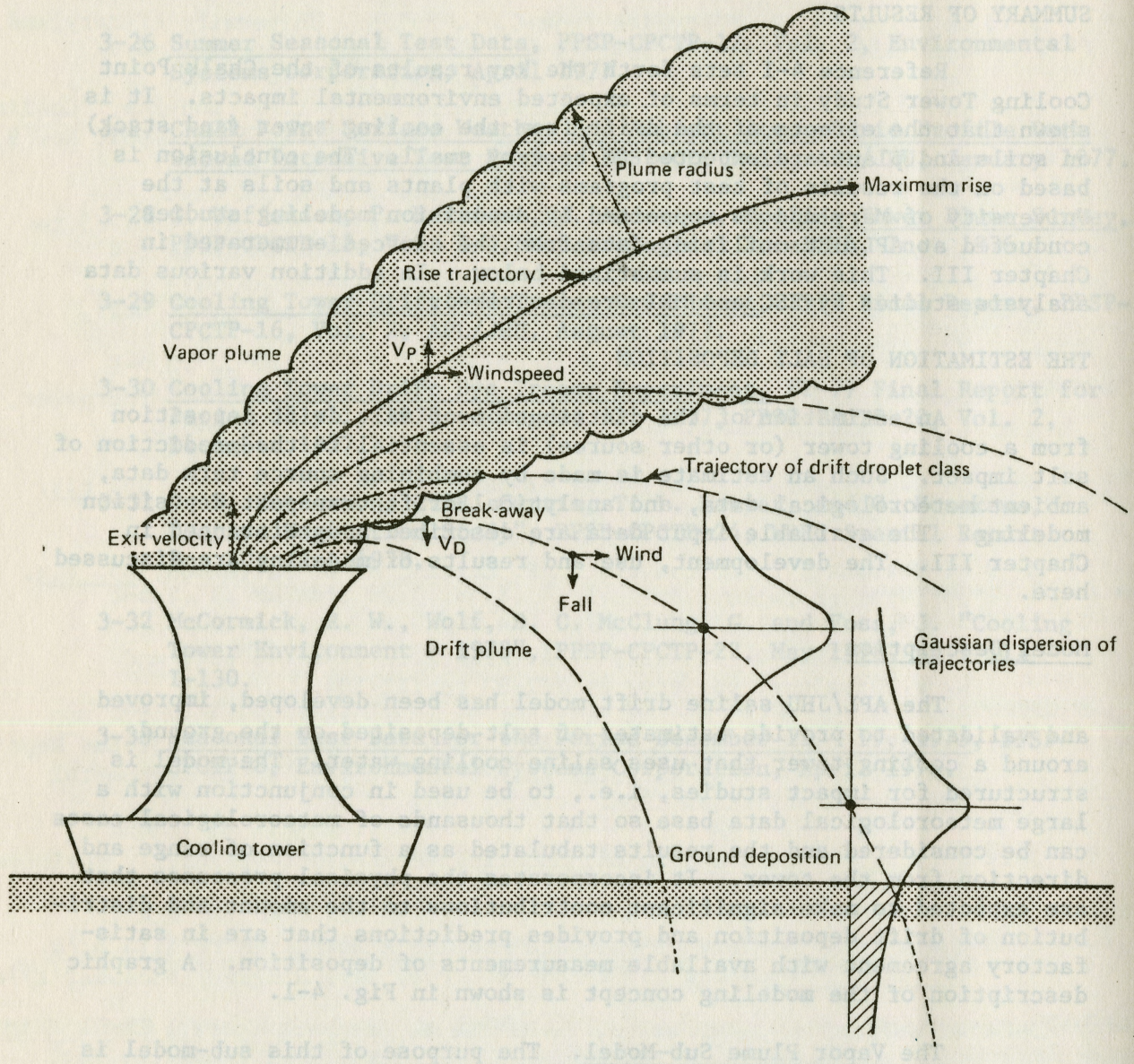


Fig. 4-1 Essential features of APL/JHU Saline drift model.

The output of the plume behavior submodel is a record of the plume rise height, plume radius, temperature and relative humidity at a given set of downwind locations. These values are then used in the drift transport submodel.

The Drift Transport/Deposition Sub-model. The purpose of this submodel is to predict the transport of saline drift after its emission from the cooling tower and to compute the deposition of salt on the soil, plants, and structures in the area surrounding the tower. The deposition of salt at a given downwind location consists of contributions from several droplet size classes. The total deposition rate at a given location is the sum of the deposition by each size class. The computation depends on three factors: the rate of saline drift from the tower, the mass of the drift in each droplet size class, and the fraction of that mass reaching the ground at that location. More details are given in Reference 4-2.

Model Validation

The APL/JHU Saline Drift Model has been validated with the deposition data obtained in the Drift Dye Tracer Experiment conducted at Chalk Point (Refs. 4-5 and 4-6). This experiment provides deposition measurements in which the Unit No. 3 cooling tower drift is uniquely separated from other sources of drift, in particular, that from the Unit No. 3 stack which uses saline water for scrubbing. The necessity for model validation is evident from the work done at Argonne National Laboratory (Ref. 4-7) and at Oak Ridge National Laboratory (Ref. 4-8) which has shown that various available salt loading models can give deposition predictions that differ by as much as two orders of magnitude.

Data can be used to validate the model in two ways: 1) to demonstrate that the model predicts the correct value of deposition at a given location under given conditions and, 2) to establish that the model gives the correct trend in the predictions, e.g., deposition variation with downwind distance. The dye tracer experimental data appears to be the only complete set of data available at the present time. Model validation against trends can often use data that is not complete in every respect but is sufficient to show trends for comparison to those predicted by the model. Some of the Chalk Point data may prove valuable in this regard.

In addition to the APL Model two other models developed earlier in the Chalk Point Cooling Tower Project have been used to compare their predictions with the Dye Tracer Experiment measurements. One is a recent version of the Overcamp-Israel model and the other is a trajectory-type model also due to Overcamp.

The model input parameters defining average meteorological and average plant conditions are given in Table 4-1. The models using these inputs were run to predict the total salt deposition at 0.5 Km and at 1.0 Km for comparison to the measured total at those ranges. This work was reported at the Symposium, Cooling Tower Environment - 1978 (Ref. 4-9).

The results which are shown in Table 4-2, indicate that the Overcamp model predicts 30 to 40 percent less total deposition than was observed at each range and comes within 15 percent of the correct ratio between the two ranges. The APL model comes within a few percent of predicting the trend with range; however, it is consistently high by about 55 percent. These predictions of total deposition are in good agreement with the observed data. On the other hand, the most significant droplet size predicted as contributing to the deposition does not agree well with the measured value. All three models do poorly in this regard especially at 1.0 Km where reasonable agreement might be expected.

Attempts to resolve this difficulty are described in Reference 4-1 and 4-2, summarized in Table 4-3 and shown graphically in Figs. 4-2 and 4-3. It should be kept in mind that the attempt to predict deposition drop size distribution provides a check on the internal consistency of the model.

The comparison of the APL Model's features with those of other models as was done in Reference 4-10 indicates that it provides a reasonable representation of the physical processes involved. From the validation effort it appears to overpredict deposition and should provide conservative estimates of salt loading impact.

Salt Deposition Predictions

The utilization of the salt drift models required that appropriate input data sets be prepared from the wide variety of data described in Chapter III. The principal data sets prepared were

Meteorological Data Base. The CPCTP data archive contains a large amount of meteorological data in useful form. With some editing this data satisfied most of the model input requirements. Other data were required to provide the remaining model inputs. For example the saline drift model uses the atmospheric stability category for its estimates of dispersion of drift droplets. It also uses upper air lapse rate in the plume rise computations. Although model estimates can be made without these parameters, model predictions are more reliable when they are used. Hence to form a complete meteorological data base for model inputs it was necessary to gather data from other sources, to combine these with the Chalk Point data into the best available estimates

TABLE 4-1

MODEL INPUT PARAMETERS FOR DYE TRACER EXPERIMENT
AVERAGE CONDITIONS

(Reproduced from Ref. 4-1)

Meteorological Parameters	
Wind Speed	6.8 ± .8 meters/sec
Wind Direction	171 ± 5 degrees from North
Ambient Temperature	20.1 ± .7°C
Temperature Lapse	0.2°C/100 meters
Relative Humidity	95 ± 4%
Stability Class	F
Tower Parameters	
Tower Height	122 meters
Tower Diameter	55 meters
Plume Exit Velocity	4.5 ± 1.2 m/sec
Plume Exit Temperature	35.6 ± 1.7°C
Drift Mass Rate	0.14 Kg/sec (0.13 Kg/sec)*
Basin Salinity (salt)	0.044 Kg/Kg
Drift Mass Fraction	Log normal above 50 μm
Mass Median Size	60 μm
95th Percentile Size	500 μm
Average Plume Parameters	
Entrainment Tuning Factor	0.6

*From basin salinity and isokinetic sampler sodium (from drift droplet counts). These quantities are equivalent to approximately 2 gal./min. of water.

TABLE 4-2

OBSERVED AND PREDICTED DRIFT SALT DEPOSITION

(Reproduced from Ref. 4-1)

Receptor Range	Deposition (Kg/Km-Mth) 500m	1000 m	Deposition Ratio (500 m to 1000 m)
Observed Total at Range	1160	596	1.95
Predicted Total at Range			
Overcamp Model (1977)	680	410	1.65
Trajectory Model (Overcamp)	1430	380	3.75
APL Model	1848	905	2.04
APL Model with Wind Profile	1800	1502	1.20
Ratio of Predicted to Observed			
Overcamp Model	0.59	0.69	
Trajectory Model (Overcamp)	1.23	0.64	
APL Model	1.59	1.52	
APL Model with Wind Profile	1.55	2.52	

TABLE 4-3

OBSERVED AND PREDICTED DEPOSITION DROP SIZE
(Reproduced from Ref. 4-1)

Downwind Range	Most Significant Drop Size (Microns) 500 m	1000 m
Observed	380	280
Models at APL/JHU		
APL	1100	430
APL with Wind Profile	550	280
Modified Overcamp	700	470
Overcamp Trajectory	700	470
Models at ANL*		
Hanna	580	380
Hosler-Pena-Pena	-	-
Overcamp-Israel	580	400
Wigley-Slawson	420	310
Slinn I	270	160
Slinn II	-	-
Wolf I	400	230
Wolf II	370	130
ESC/Schrecker	430	260
MRI	-	-
Wigley-Slawson	490	360
ESC/Schrecker (Limited)	420	260

*Reference 14

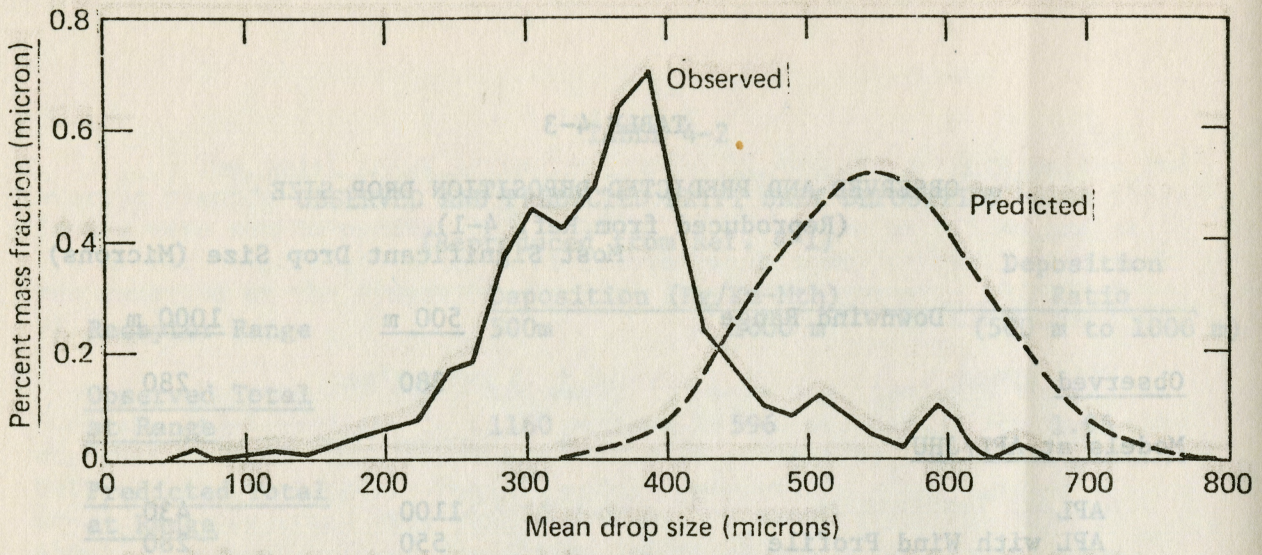


Fig 4-2 Predicted and observed deposition mass fraction at 0.5 km Chalk Point dye tracer experiment (APL model with profiled wind)

(Reproduced from Ref. 4-1)

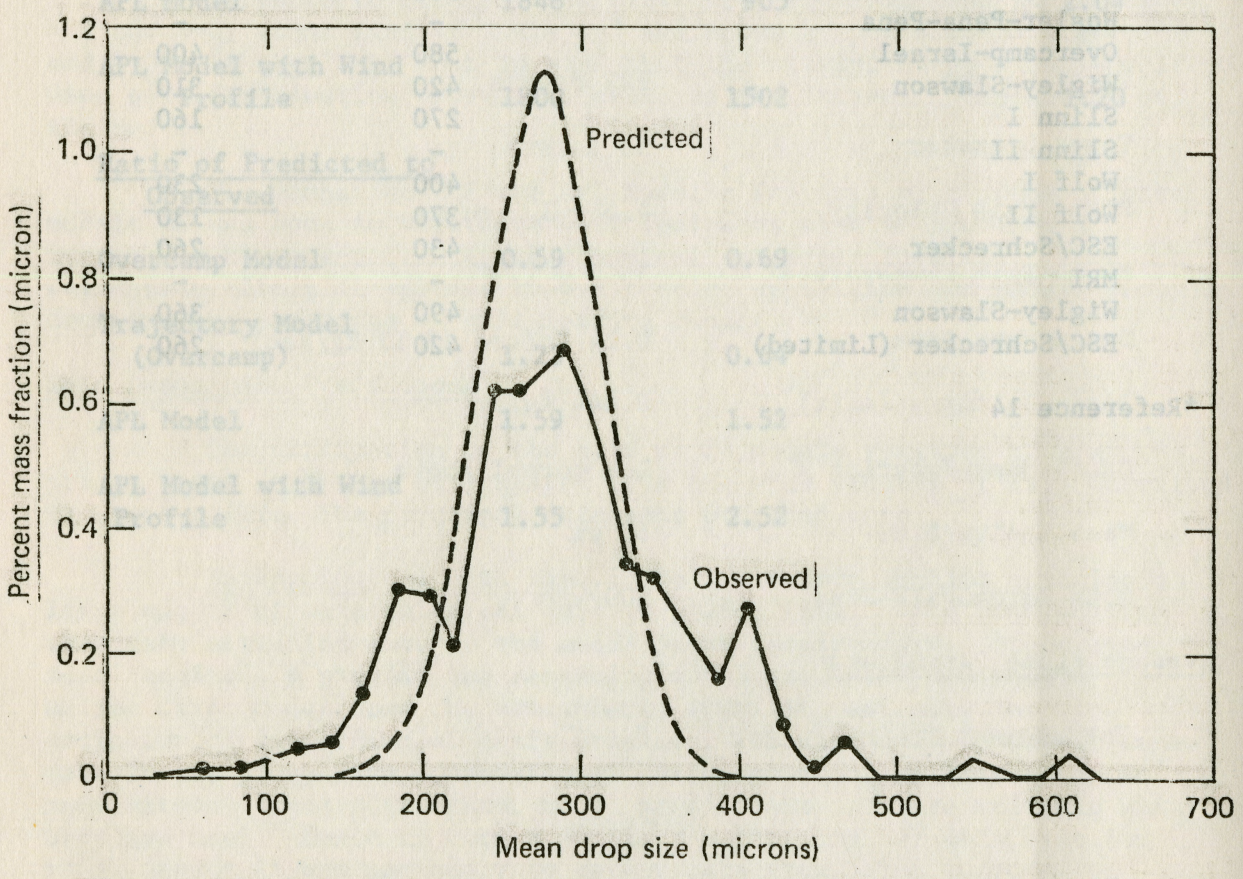


Fig. 4-3 Predicted and observed deposition mass fraction at 1.0 km Chalk Point dye tracer experiment (APL model with profiled wind)

(Reproduced from Ref. 4-1)

of each model input, and to properly handle missing data. The data sources used were

1) Chalk Point Meteorological Tower Data for 1975, 1976 and 1977.

2) Chalk Point Rawinsonde Data for December 1975 and June 1976.

3) Dulles Rawinsonde taken twice daily for two years of interest.

4) Andrews Air Force Base hourly surface observations.

The content of the meteorological data base is described fully in Reference 4-1. It is a fully edited 3-hour average sampling of all data needed as meteorological inputs to the model. It is available on tape from the CPCTP data archives at APL/JHU.

Tower and Plume Characteristics. The plume behavior model requires input parameters to compute plume rise, radius, temperature and relative humidity. The parameters of interest are listed in Table 4-4. The values given for these parameters have been obtained by analysis of the data reported in References 3-26 and 3-27. For the most part attention was limited to the data collected in the Winter Seasonal Test (December 1975) and the Summer Seasonal Test (June 1976). The data collected during these intensive tests provide complete time coincident measurements of cooling tower exit conditions, photographic records of plume behavior, frequent measurements of ambient meteorology from the met tower, and observations of upper air meteorology from rawinsondes. Since detailed tower and plume characteristics are available only for one week in the summer and one week in the winter, it was necessary to develop inputs from these data for use throughout the year. The methods used are described in Reference 4-1. Figures 4-4 and 4-5 give plots of these relationships. It is seen that these parameters are mainly dependent on ambient temperature.

Predicted Deposition from Unit No.3 Cooling Tower

The model was exercised utilizing the data inputs as summarized above and as described in detail in References 4-1 and 4-2. Plume exit velocity and exit temperature were computed as described above and a 17 ppt basin salinity value was used.

The total salt emitted from the Unit No. 3 cooling tower with the plant operating at full load (average 590 MWe) is tabulated in Table 4-5 on a monthly, seasonal and annual basis. The tabulation is

TABLE 4-4

TYPICAL TOWER AND PLUME CHARACTERISTICS*
(Reproduced from Ref. 4-1)

	Summer	Winter
Plant Load (MWe)	590	590
Ambient Temperature (°C)	25.2	4.4
Ambient Relative Humidity (%)	70	48
Plume Exit Velocity (m/sec)	4.5 ± 1.3	4.2 ± 1.1
Plume Exit Temperature (°C)	37.5 ± 1.8	24.6 ± 1.9
Plume Entrainment Coefficient, γ	1.1 ± .4	0.6 ± .2
Ratio Upper to Lower Windspeed	1.17	1.0
Basin Salinity (ppt salt)	17 ± 3	9 ± 4
Drift Mass Rate (Kg/sec)	0.16 ± .02	0.12 ± .04
Drift Droplet Mass Fraction	log normal	log normal
Mass Median Droplet Size (μm)	76 ± 15	79 ± 25
10th Percentile Size (μm)	20 ± 6	17 ± 5
90th Percentile Size (μm)	290 ± 60	360 ± 150

*Based on seasonal test measurements at Chalk Point

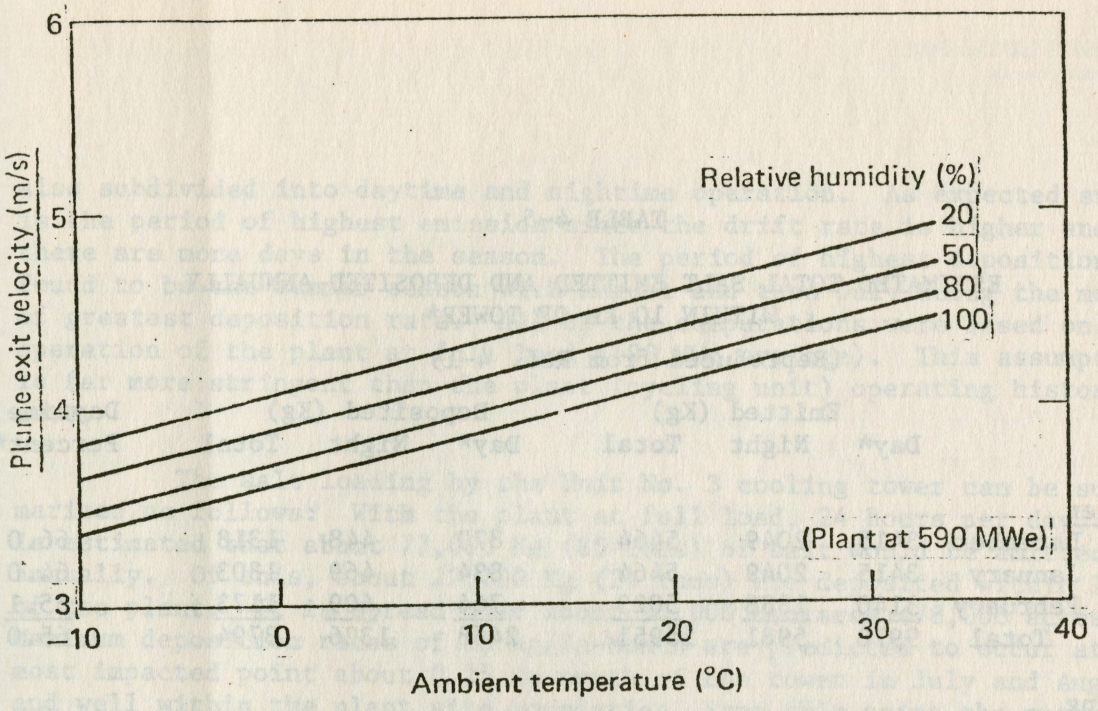


Figure 4-4. Estimate of plume exit velocity
(Reproduced from Ref. 4-1)

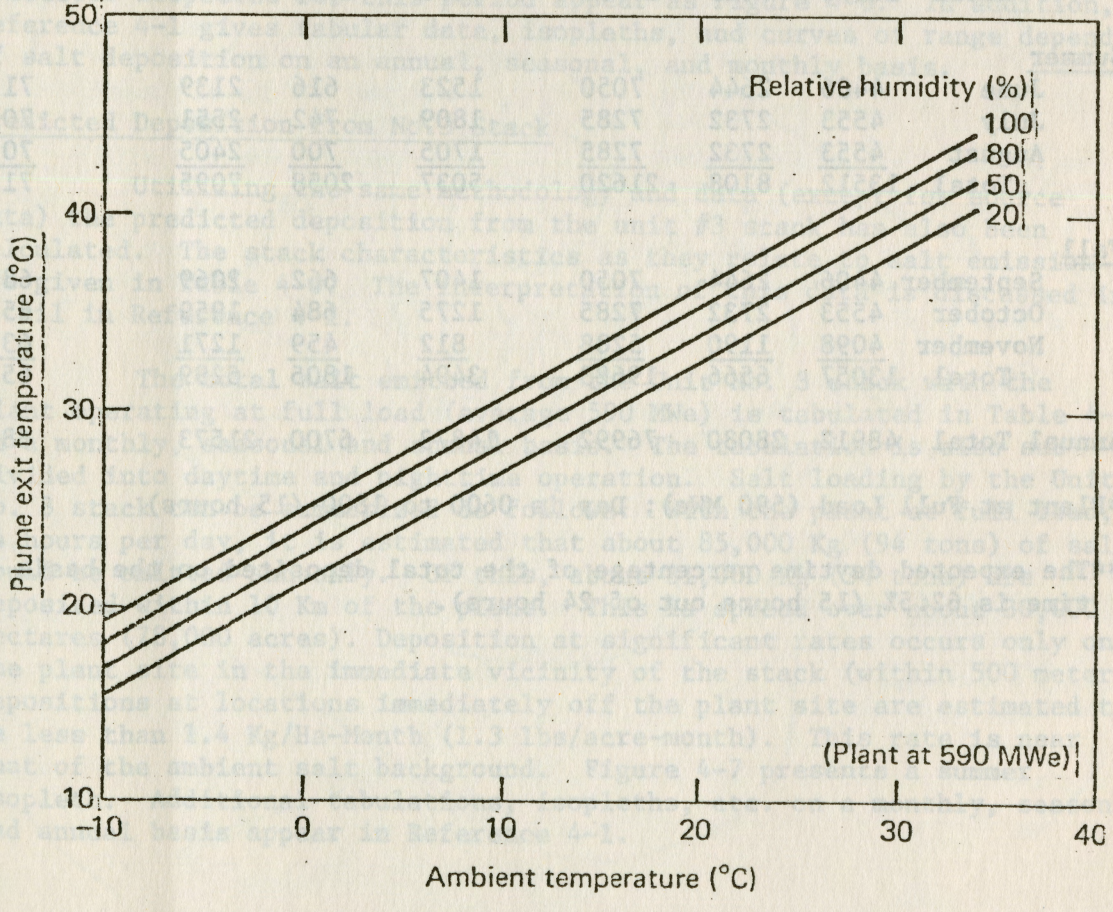


Figure 4-5. Estimate of plume exit temperature
(Reproduced from Ref. 4-1)

TABLE 4-5

ESTIMATED TOTAL SALT EMITTED AND DEPOSITED ANNUALLY WITHIN 10 Km OF TOWER*

(Reproduced from Ref. 4-1)

	Emitted (Kg)			Deposited (Kg)			Daytime
	Day*	Night	Total	Day*	Night	Total	Percent**
Winter							
December	3415	2049	5464	870	448	1318	66.0
January	3415	2049	5464	834	469	1303	64.0
February	3140	1883	5023	764	409	1173	65.1
Total	9970	5981	15951	2468	1326	3794	65.0
Spring							
March	3415	2049	5464	916	413	1329	68.9
April	4406	2644	7050	1419	510	1929	73.6
May	4553	2732	7285	1539	587	2126	72.4
Total	12374	7425	19799	3873	1510	5383	71.9
Summer							
June	4406	2644	7050	1523	616	2139	71.2
July	4553	2732	7285	1809	742	2551	70.9
August	4553	2732	7285	1705	700	2405	70.9
Total	13512	8108	21620	5037	2058	7095	71.0
Fall							
September	4406	2644	7050	1407	662	2069	68.0
October	4553	2732	7285	1275	684	1959	65.1
November	4098	1190	5288	812	459	1271	63.9
Total	13057	6566	19623	3494	1805	5299	65.9
Annual Total	48912	28080	76992	14873	6700	21573	68.9

*Plant at Full Load (590 MWe); Day is 0600 to 1800 (15 hours)

**The expected daytime percentage of the total deposited on the basis of time is 62.5% (15 hours out of 24 hours).

also subdivided into daytime and nightime operation. As expected summer is the period of highest emission since the drift rate is higher and there are more days in the season. The period of highest deposition was found to be the summer season with August and then July being the months of greatest deposition rate. All of the computations were based on operation of the plant at full load (590 MWe average). This assumption is far more stringent than the plant (cycling unit) operating history to date.

The salt loading by the Unit No. 3 cooling tower can be summarized as follows: With the plant at full load, 24 hours per day, it is estimated that about 77,000 Kg (85 tons) of salt would be emitted annually. Of this, about 22,000 Kg (24 tons) are deposited within 10 Km of the plant. It is spread over about 30,000 hectares (78,000 acres). Maximum deposition rates of 13 Kg/Ha-Month are predicted to occur at the most impacted point about 0.25 Km north of the tower in July and August and well within the plant site boundaries. From this point the rate decreases rapidly with distance. Maximum off-site rates are typically under 1 Kg/Ha-Month (less than 1 lb/acre-month) with a maximum rate of 1 Kg/Ha-Month occurring during the summer 1 Km south of the tower. The predicted isopleths for this period appear as Figure 4-6. In addition, Reference 4-1 gives tabular data, isopleths, and curves of range dependence of salt deposition on an annual, seasonal, and monthly basis.

Predicted Deposition from No.3 Stack

Utilizing the same methodology and data (except for source data) the predicted deposition from the unit #3 stack has also been calculated. The stack characteristics as they relate to salt emission are given in Table 4-6. The interpretation of this data is discussed in detail in Reference 4-1.

The total salt emitted from the Unit No. 3 stack with the plant operating at full load (average 590 MWe) is tabulated in Table 4-7 on a monthly, seasonal and annual basis. The tabulation is also subdivided into daytime and nighttime operation. Salt loading by the Unit No. 3 stack can be summarized as follows: With the plant at full load, 24 hours per day, it is estimated that about 85,000 Kg (94 tons) of salt would be emitted annually. Of this, about 31,000 Kg (34 tons) are deposited within 10 Km of the plant. This is spread over about 30,000 hectares (78,000 acres). Deposition at significant rates occurs only on the plant site in the immediate vicinity of the stack (within 500 meters). Depositions at locations immediately off the plant site are estimated to be less than 1.4 Kg/Ha-Month (1.3 lbs/acre-month). This rate is near that of the ambient salt background. Figure 4-7 presents a summer isopleth. Additional tabulations, isopleths, etc. on a monthly, seasonal, and annual basis appear in Reference 4-1.

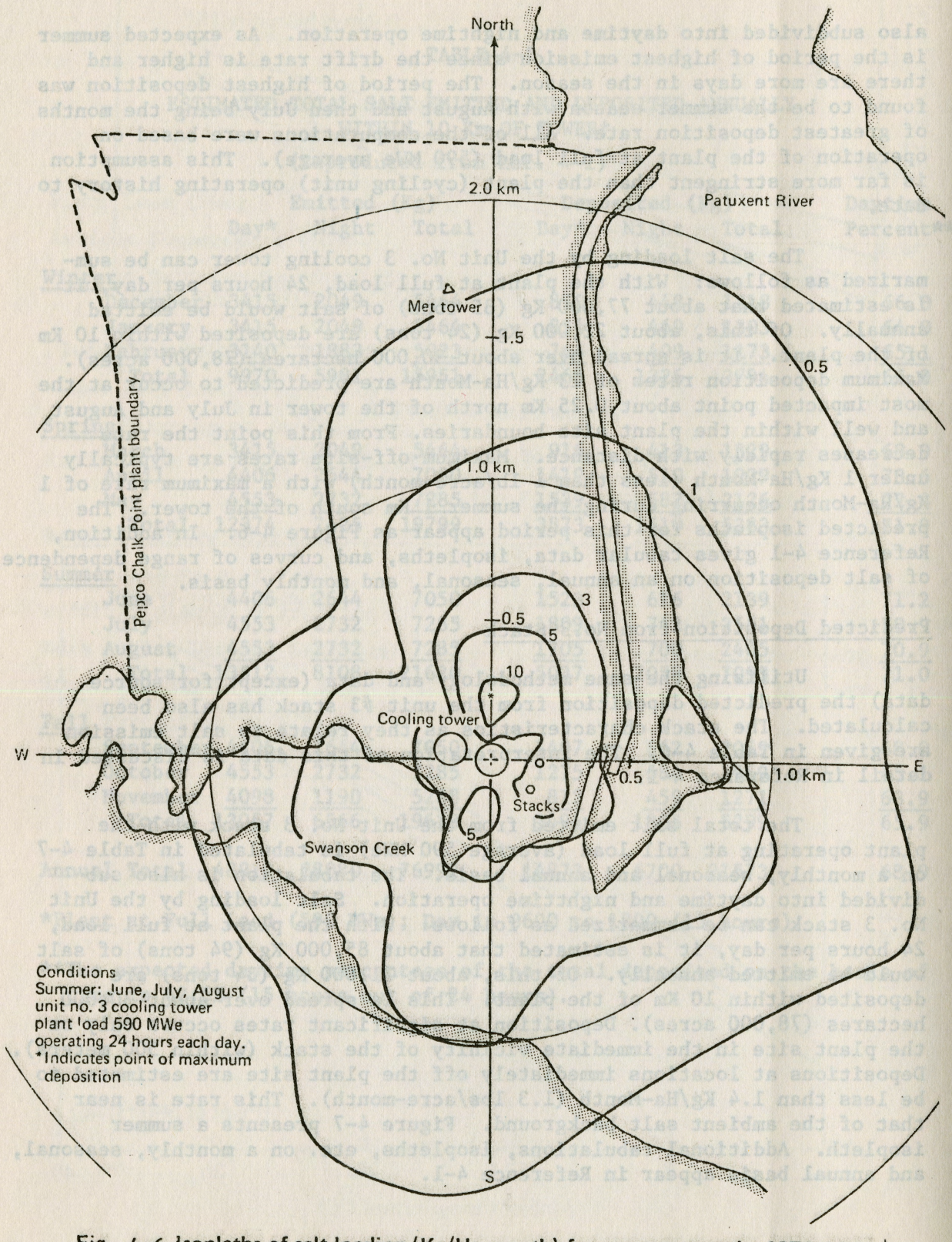


Fig. 4-6 Isopleths of salt loading (Kg/Ha-month) for summer months 1976-1977. (from Cooling Tower)
(Reproduced from Ref. 4-1)

TABLE 4-6 CHARACTERISTICS OF UNIT NO. 3 STACK

(Reproduced from Ref. 4-1)

Stack Configuration

Height	217 meters
Diameter	7.6 meters

Emission Parameters

Plant Load	590 MWe
Plume Exit Velocity	16.1 ± 1 m/sec
Plume Exit Temperature	57.5 ± 3 °C
Plume Entrainment Coefficient	0.6
Ratio Upper to Lower Windspeed	1.0

Drift Parameters

Basin Water Salinity	
Summer Test	18.2 ppt salt
Winter Test	12.2 ppt salt
Drift Mass Rate*	0.15 Kg/sec
Drift Droplet Mass Fraction	log normal
Mass Median Droplet Size	130 μm
10th Percentile Size	30 μm
90th Percentile Size	560 μm

*Based on isokinetic sodium sampler and basin salinity.

TABLE 4-7

ESTIMATED TOTAL SALT EMITTED AND DEPOSITED ANNUALLY BY UNIT NO. 3 STACK WITHIN 10 Km OF PLANT*

(Reproduced from Ref. 4-1)

	Emitted (Kg)			Deposited (Kg)			Daytime
	Day*	Night	Total	Day*	Night	Total	Percent**
Winter							
December	4520	2710	7230	1615	887	2502	64.5
January	4520	2710	7230	1582	907	2489	63.6
February	4154	2493	6647	1370	756	2126	64.4
Total	13194	7913	21107	4567	2550	7117	64.2
Spring							
March	4520	2710	7230	1566	818	2384	65.7
April	4376	2623	6999	1658	754	2412	68.7
May	4520	2710	7230	1776	821	2597	68.4
Total	13416	8043	21459	5000	2393	7393	67.6
Summer							
June	4376	2623	6999	1787	845	2632	67.9
July	4520	2710	7230	2059	983	3042	67.7
August	4520	2710	7230	2018	944	2962	68.1
Total	13416	8043	21459	5864	2772	8636	67.9
Fall							
September	4376	2623	6999	1735	885	2620	66.2
October	4520	2710	7230	1589	894	2483	64.0
November	4376	2623	6999	1560	915	2475	63.0
Total	13272	7956	21228	4884	2694	7578	64.4
Annual Total	53298	31955	85253	20315	10409	30724	66.1

*Plant at Full Load (590 MWe); Day is 0600 to 1800 (15 hours)

**The expected daytime percentage of the total deposited on the basis of time is 62.5% (15 hours out of 24 hours).

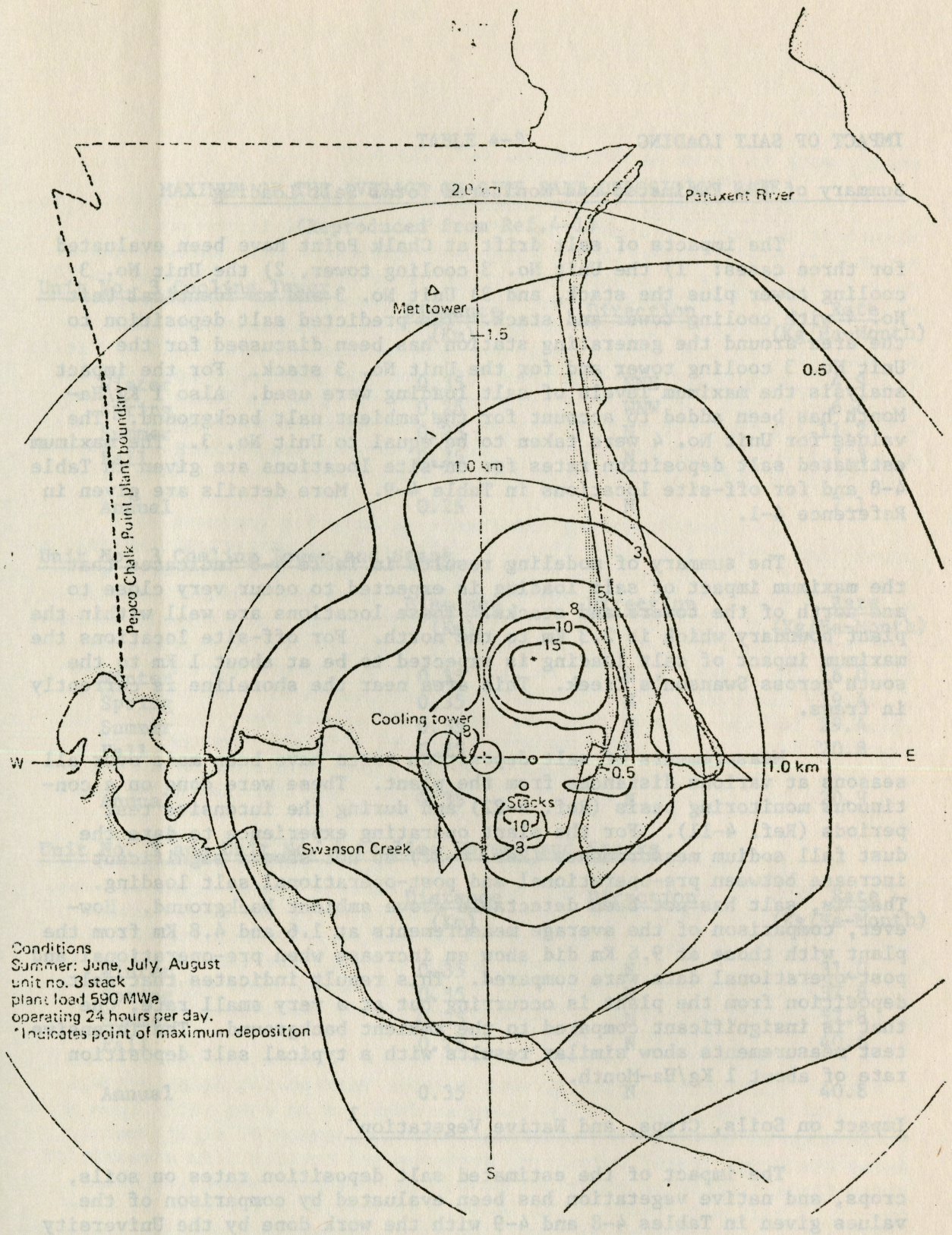


Figure 4-7. Isopleths of Salt Loading (Kg/Ha-Month) for summer months 1976-1977. (from No. 3 Stack)

(Reproduced from Ref. 4-1)

IMPACT OF SALT LOADING

Summary of the Estimated and Monitored Total Salt Loading

The impacts of salt drift at Chalk Point have been evaluated for three cases: 1) the Unit No. 3 cooling tower, 2) the Unit No. 3 cooling tower plus the stack, and 3) Unit No. 3 and an identical Unit No. 4 with cooling tower and stack. The predicted salt deposition to the area around the generating station has been discussed for the Unit No. 3 cooling tower and for the Unit No. 3 stack. For the impact analysis the maximum levels of salt loading were used. Also 1 Kg/Ha-Month has been added to account for the ambient salt background. The values for Unit No. 4 were taken to be equal to Unit No. 3. The maximum estimated salt deposition rates for on-site locations are given in Table 4-8 and for off-site locations in Table 4-9. More details are given in Reference 4-1.

The summary of modeling results in Table 4-8 indicates that the maximum impact of salt loading is expected to occur very close to and north of the towers and stacks. These locations are well within the plant boundary which is 2.3 Km to the north. For off-site locations the maximum impact of salt loading is expected to be at about 1 Km to the south across Swanson's Creek. This area near the shoreline is currently in trees.

Measurements of salt deposition rates have been made over all seasons at various distances from the plant. These were done on a continuous monitoring basis (Ref. 4-22) and during the intensive test periods (Ref. 4-11). For the plant operating experience to date the dust fall sodium measurements (Ref. 4-22) do not show a significant increase between pre-operational and post-operational salt loading. That is, salt has not been detectable above ambient background. However, comparison of the average measurements at 1.6 and 4.8 Km from the plant with those at 9.6 Km did show an increase when pre-operational and post-operational data were compared. This result indicates that salt deposition from the plant is occurring but at a very small rate, one that is insignificant compared to the ambient background. The intensive test measurements show similar results with a typical salt deposition rate of about 1 Kg/Ha-Month.

Impact on Soils, Crops, and Native Vegetation[1]

The impact of the estimated salt deposition rates on soils, crops, and native vegetation has been evaluated by comparison of the values given in Tables 4-8 and 4-9 with the work done by the University of Maryland in determining the effects of salt on plants and soils. This work is reported in References 4-12 through 4-30. A summary of

[1] All impact analysis relating to soils and plants has been done by the Agronomy Department of the University of Maryland.

TABLE 4-8

MAXIMUM OF THE AVERAGE ON-SITE SALT DEPOSITION RATE

(Reproduced from Ref.4-1)

Unit No. 3 Cooling Tower

	Distance (Km)	Direction	Rate (Kg/Ha-Month)
Winter	0.35	NNE	4.9
Spring	0.25	WNW	6.6
Summer	0.25	N	11.2
Fall	0.25	N	7.3
Annual	0.25	N	7.1

Unit No. 3 Cooling Tower and Stack

	Distance (Km)	Direction	Rate (Kg/Ha-Month)
Winter	0.35	N	16.0
Spring	0.35	N	19.4
Summer	0.35	N	29.4
Fall	0.25	N	20.8
Annual	0.35	N	20.9

Unit No. 3 and Unit No. 4 Cooling Towers and Stacks

	Distance (Km)	Direction	Rate (Kg/Ha-Month)
Winter	0.35	N	31.0
Spring	0.35	N	37.8
Summer	0.35	N	57.8
Fall	0.25	N	40.6
Annual	0.35	N	40.8

recent work is given in References 4-22 and 4-23.

Soil Impacts. One mechanism for the impact of saline drift on plants is through the absorption of salt accumulated in the soil. Accumulation will occur if the annual deposition of salt exceeds the rate at which salt is washed from the soil by rainfall. The results of studies (Ref. 4-28) with several Chalk Point soil types (sandy loams) suggests that deposition of 100 Kg/Ha-Month of NaCl can cause some accumulation of salt in the soil. Other experiments (Ref. 4-18) indicate that smaller deposition rates cause no accumulation. A comparison of this result with the annual average deposition rates in Tables 4-8 and 4-9 indicate that for the soil types investigated there will be no accumulation of salt in the soil. An estimate of the maximum buildup is described in Ref. 4-1 and summarized in Table 4-10.

The plant operating experience to date has produced salt deposition levels far below those in Table 4-9. As expected chemical analyses of soil samples collected from undisturbed soil research plots at twelve monitoring sites near Chalk Point have not revealed significant changes in key parameters such as soil acidity (pH), extractable sodium and chloride and electrical conductivity since the tower became operational. The slight increase in extractable sodium and electrical conductivity observed in the 1976 samples returned in 1977 to the levels observed for the 1973-75 samples. One would expect year to year fluctuations depending on salt deposition rates, rainfall amounts, etc. However, no net buildup of salts appears to have occurred in the 1977 soil samples following two years of operations for Unit No. 3 at Chalk Point.

Impacts on Crops. Direct salt damage is due to the absorption of salt from drift that is deposited on a plant's leaves. The absorbed salt then causes immediate damage or accumulates in the woody tissue of perennial plants until it reaches toxic levels. Plot studies have been performed utilizing simulated saline drift during the time between plant emergence and maturity. This type of experiment is most applicable to crops which are harvested on reaching maturity. Work on perennial vegetation is also described.

Tests were conducted over a three year period using aerosol sprays of approximately 100 μm diameter droplets at dose rates from zero to as high as 90 Kg/Ha-Month during a growing season of eight weeks. Among the crops tested were corn, soybeans and tobacco. As a result of these tests regression equations have been developed summarizing the impact of saline aerosols. The measure of impact in the case of corn and soybeans is the percent reduction in yield due to the salt deposition. The regression equations which relate yield reduction to salt deposition rate for corn and soybeans are developed in References 4-22 and 4-31.

TABLE 4-9

MAXIMUM OF THE AVERAGE OFF-SITE SALT DEPOSITION RATE

(Reproduced from Ref. 4-1)

Unit No. 3 Cooling Tower

	Distance (Km)	Direction	Rate (Kg/Ha-Month)
Winter	1.0	S	1.6
Spring	0.8	SW	1.8
Summer	1.0	S	2.0
Fall	1.0	S	1.7
Annual	1.0	S	1.7

Unit No. 3 Cooling Tower and Stack

	Distance (Km)	Direction	Rate (Kg/Ha-Month)
Winter	1.0	S	3.0
Spring	0.8	SW	3.0
Summer	1.0	S	3.2
Fall	1.0	S	3.0
Annual	1.0	S	2.9

Unit No. 3 and Unit No. 4 Cooling Towers and Stacks

	Distance (Km)	Direction	Rate (Kg/Ha-Month)
Winter	1.0	S	5.0
Spring	0.8	SW	5.0
Summer	1.0	S	5.4
Fall	1.0	S	5.0
Annual	1.0	S	4.8

TABLE 4-10
MAXIMUM OFF-SITE SALT BUILDUP IN SOIL FROM SALT DRIFT AT CHALK POINT

(Reproduced from Ref. 4-1)

	Maximum Deposition (Kg/Ha)
Unit No. 3 Cooling Tower	4.0
Unit No. 3 Cooling Tower and Stack	6.4
Units No. 3 and No. 4 Cooling Towers and Stacks	10.8

TABLE 4-11
MAXIMUM EFFECT OF OFF-SITE SALT DEPOSITION ON CROPS

(Reproduced from Ref. 4-1)

	Maximum Deposition of Salt (Kg/Ha-Mth)	Reduction in Yield of Corn (%)	Reduction in Yield of Soybeans (%)	Reduction in Tobacco Burn Time (%)
Unit No. 3 Tower	2.0	1	0	0
Unit No. Tower and Stack	3.2	1	0	0
Units No. 3 and No. 4 Cooling Towers and Stacks	5.4	2	0	0

In the case of tobacco the yield is unaffected by or actually increased slightly by moderate salt loading. However, the salt deposition causes an increase in the chloride level of the tobacco leaf which reduces its quality due to an undesirable change in the burning properties. Hence the proper impact measure for tobacco is the change in burning quality. This is estimated with two regression equations (Ref.4- 31), one relating the chloride content of a tobacco leaf to the salt deposition rate and the other relating the chloride content to the percent reduction in burning time. Results are given in Table 4-11.

Impact on Native Vegetation. A series of simulated salt drift (spray) experiments has been performed to examine the effects on native perennials. The species tested include dogwood, Virginia pine, tulip poplar, Norway spruce, white ash and California privet. Significant effect was demonstrated with dogwood (Refs. 4-18 and 4-25).

Assessment of the impact of the salt drift on dogwood is somewhat difficult for a number of reasons. First, the trees were sprayed for only two months, not the entire growing season. Secondly, there is evidence that at some level of deposition the trees accumulate chloride ion in woody tissue (Refs. 4-18, 4-21 and 4-24). In subsequent years, this stored chloride can be released to the leaves increasing the tree's sensitivity to saline drift. Lastly, the application of the spray to the plots during the simulated drift experiments was not uniform. The possible deposition rates vary by a factor of five. In this analysis the estimate of the deposition used is that of Reference 4-18. This value may tend to overestimate the sensitivity of dogwood. Balancing this is the longer period of exposure and the tendency to bioconcentrate chloride.

Regression equations have been developed that relate the percent of leaves damaged to the leaf chloride content (Refs. 4-18 and 4-24) and the leaf chloride content to salt deposition rate. The predicted affects are given in Table 4-12 for on-site dogwood and in Table 4-13 for off-site dogwood. The results indicate that significant leaf damage would occur for dogwood trees at on-site locations with maximum salt loading. Some leaf damage would also occur to off-site dogwood at locations of maximum salt loading, especially with both Units No. 3 and No. 4 operating full time. In the spray experiments the damage to the dogwood was short term with the leaves returning normally in the next growing season. Once again it should be pointed out that operating experience to date is well below the maximum levels assumed in the estimates. Further details are given in Reference 4-1.

Damage to Man-Made Structures

Salt drift from cooling towers has the potential to accelerate the corrosion of materials exposed to it. The amount of acceleration is

TABLE 4-12
EFFECTS OF MAXIMUM ON-SITE SALT DEPOSITION ON DOGWOOD
(Reproduced from Ref. 4-1)

	Deposition Rate (Kg/Ha-Month)	Leaves Damaged (Percent)
Unit No. 3 Cooling Tower	11.2	33
Unit No. 3 Cooling Tower and Stack	29.4	63
Units No. 3 and No. 4 Cooling Towers and Stacks	57.8	86

TABLE 4-13
EFFECTS OF MAXIMUM OFF-SITE SALT DEPOSITION ON DOGWOOD
(Reproduced from Ref. 4-1)

	Deposition Rate (Kg/Ha-Month)	Leaves Damaged (Percent)
Unit No. 3 Cooling Tower	2.0	0
Unit No. 3 Cooling Tower and Stack	3.2	0
Units No. 3 and No. 4 Cooling Towers and Stacks	5.4	13

dependent not only on the amount of extra salt deposited by the drift, but also on the amount of water deposited with the drift, the temperature, other atmospheric pollutants in the area, and the presence or absence of natural water, its type (fog, snow, or rain), and its intensity.

As an example, higher corrosion rates will be associated with salt solutions that remain in contact with the surface being corroded for long periods of time. Heavy rain would tend to wash away and reduce damage, but fog would allow the salt solution to remain in contact with the surface and continue the corrosive process.

The ocean coast is a severe environment for metals and painted surfaces. Airborne salt drift from the ocean accelerates the weathering and corrosion of exposed structures. Coastal sites, for example, Point Reyes, California, and Kure Beach, North Carolina, are used by the American Society for Testing and Materials to accelerate the testing of the effectiveness of metal alloys and coatings in resisting corrosion and weathering. Corrosion effects have been shown to decrease rapidly with distance from the shoreline. A few examples will be cited.

Thomas and Alderson have compared the rates of corrosion of steel in coastal, industrial, refinery, and rural areas of California (Ref. 4-32). The coastal areas produced the highest rates of corrosion. At a site in Sutro, San Francisco, at 90 meters from the shore, the corrosion rate was 7.86 mil/yr. The corrosion rate at Bodega Bay, 150 meters from the shore, was 1.89 mil/yr, and the rate at Point Reyes, 580 meters from the shore, was 1.11 mil/yr. These can be compared to the corrosion rate of 0.32 mil/yr measured at Davis, a rural area. Corrosion of steel structures at Inco's testing station at Kure Beach, North Carolina (Ref. 4-33), showed a typical corrosion rate of 15 mil/yr on a structure located 50 meters from the ocean. The rate 25 meters from the ocean was 12 times that observed 250 meters inshore. Ambler and Bain studied mild steel in the tropical environment of Nigeria where corrosion rates of 30 mil/yr were found (Ref. 4-34). There was a tenfold reduction in corrosion within the first 1000 meters from the ocean. The graphs in the report show an approximate reduction in corrosion rates of a factor of 10 moving from an area with a salt deposition rate of 240 Kg/Ha-Month to one with 24 Kg/Ha-Month and a further reduction by approximately a factor of 10 moving to an area with a deposition rate of 2.4 Kg/Ha-Month. In a study of zinc corrosion rates in Nigeria (Ref. 4-33), corrosion rates dropped by a factor of 5 from a distance 360 meters from the shore where the salt deposition was 10 Kg/Ha-Month to a distance of 1200 meters where the deposition rate was 4.8 Kg/Ha-Month. Other studies in the United States have shown that the rate of zinc corrosion decreases by a factor of 6 moving from 25 meters to 250 meters inland (Ref. 4-35) and the rate of aluminum corrosion decreases by a factor of 21 over the same distance (Ref. 4-36).

The weathering and corrosion of materials exposed to a deposition of greater than 8 Kg/Ha-Month will be approximately equal to that within 1 Km of the ocean coast. Based on Tables 4-8 and 4-9 accelerated corrosion would appear to be confined to the plant site where it could constitute a significant problem. There does not appear to be a potential for significant enhancement of corrosion damage off of the plant site.

RESULTS OF THE ESC ANALYSIS PROGRAM

The primary roles of ESC in the Chalk Point Cooling Tower program have been in the areas of data acquisition and data reduction. ESC has not been funded to conduct a comprehensive data analysis program; however, in FY 1977, ESC did conduct a preliminary analytical screening of cooling tower emission data and ambient salt concentration data. This work appears in Reference 4-11. A brief summary of each of these two areas of data analysis follows.

Cooling Tower Emission Data Analysis. The source term data (including meteorology) from Initial Characterization, Seasonal Intensive Tests, and Continuous Monitoring have been collected and screened for trends and gross functional relationships. Tables of data from the various test phases are included in Reference 4-11. All of these data have been used by ESC in a search for trends. Over thirty two-function plots were constructed with relatively inconclusive results. In a few cases, intuitively reasonable results appear to be evident from the data, although the scatter is very wide (see Figure 4-8). In other cases in which one would expect an observable trend, none can be seen (see Figure 4-9) in which the summer-to-winter variation is the only prominent feature and the expected increase in mass emission with updraft velocity is not apparent.

The immediately obvious features of the data are that the liquid drift emission during the summer tests is approximately twice that observed during the winter and the mass median diameter for summer is significantly greater than the value for the winter season. Beyond these observations, this first screening of the emission data is not very revealing. ESC has drawn the following conclusions from this data screening process:

"Of the more than 30 comparisons of cooling tower emissions data with plant and meteorological conditions which are presented here (Reference 4-11) the dominant observable trends are listed below:

1. Plant Operation

   a. Increase in liquid drift with increasing Unit #3 load.

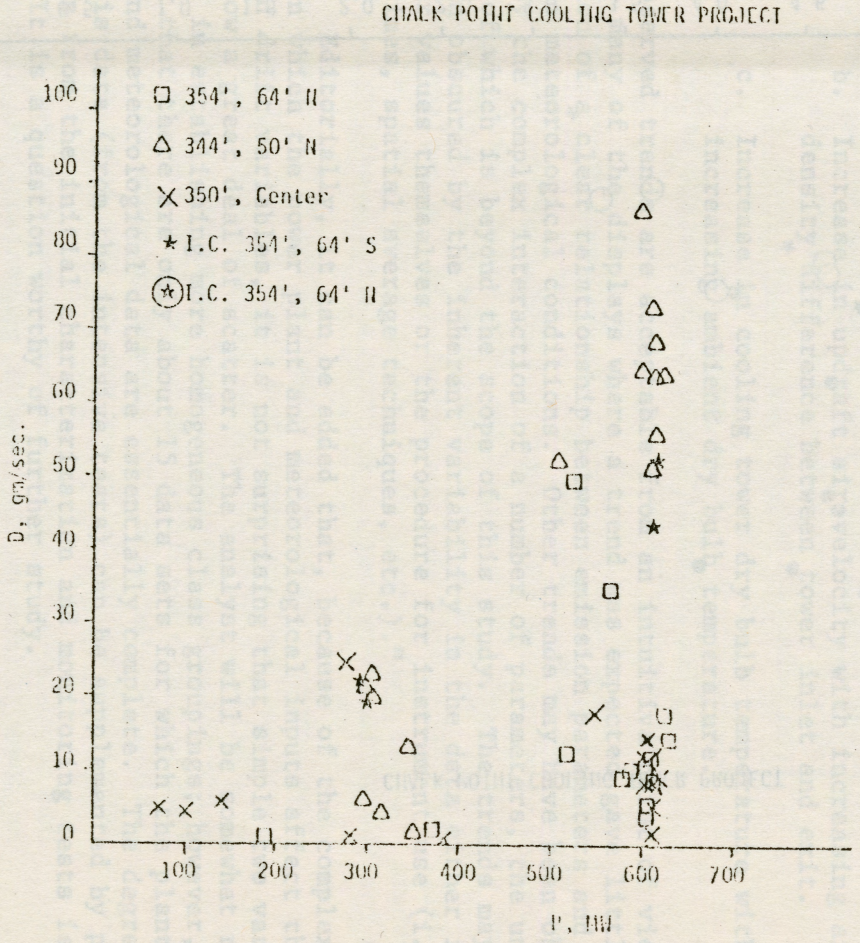


Fig. 4-8 Drift Mass Emission versus Unit #3 Load (Point Measurements) Reproduced from Ref. 4-11

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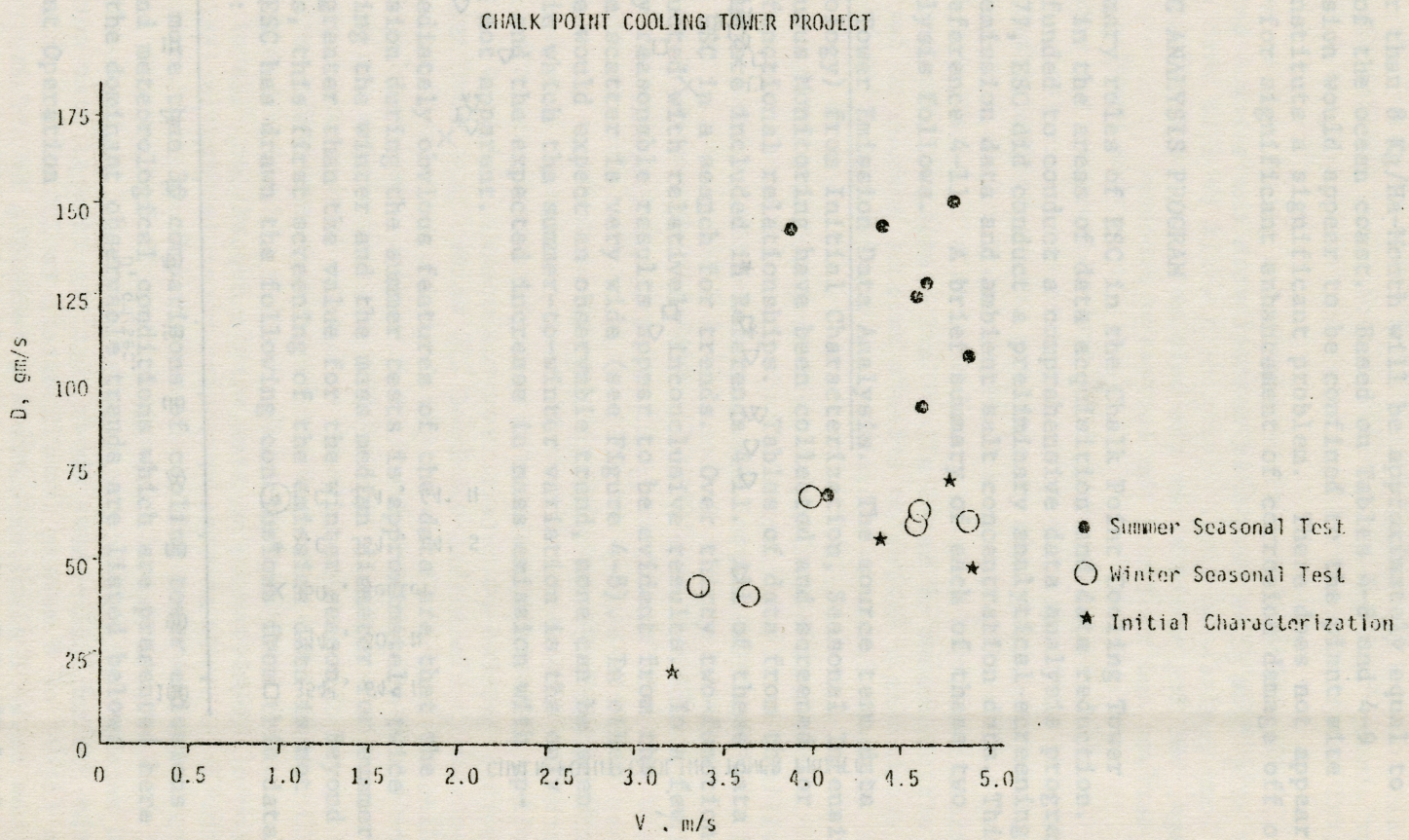


Fig. 4- 9. Liquid Drift Mass Emission versus Updraft Air Velocity

Reproduced from Ref. 4-11

b. Increase in updraft air velocity with increasing range.

c. Increase in liquid drift with increasing updraft air velocity (which should follow from 1 and 2).

d. Increase in droplet MMD with increasing updraft air velocity.

e. Increase in sodium mass emission with increasing basin water sodium concentrations.

2. Meteorological Conditions

a. Increase in liquid drift mass emission with increasing relative humidity.

b. Increase in updraft air velocity with increasing air density difference between tower inlet and exit.

c. Increase in cooling tower dry bulb temperature with increasing ambient dry bulb temperature.

These observed trends are acceptable from an intuitive point of view; however, many of the displays where a trend was expected gave little indication of a clear relationship between emission parameters and the plant and meteorological conditions. Other trends may have been obscured by the complex interaction of a number of parameters, the unfolding of which is beyond the scope of this study. The trends may also have been obscured by the inherent variability in the data either in the parameter values themselves or the procedure for instrument use (i.e., sample times, spatial average techniques, etc.)."

Editorially, it can be added that, because of the complex manner in which the power plant and meteorological inputs affect the plume and drift variables, it is not surprising that simple two variable plots show a great deal of scatter. The analyst will be somewhat restricted in establishing more homogeneous class groupings; however, by the fact that there are only about 15 data sets for which the plant, plume, and meteorological data are essentially complete. The degree to which this data (from the intensive tests) can be supplemented by partial data sets from the initial characterization and monitoring tests is not clear. It is a question worthy of further study.

Ambient Salt Concentration Data. Figure 3-16 (Chapter III) presents the site plan of ambient salt monitoring. Prior to September 5, 1975, data were taken at sites 1N, 3N, 1E, 3S and 6W. After that date, these sites were replaced by the other sites shown. In September 1975, a change was made to replace the polyester mesh salt sampler of

the airborne particle sampler (APS) tungsten mesh sampler. Procedural background corrections have been made to all the data.

Data used in ambient background studies consists of APS data taken when Unit #3 were not on line. This includes all data taken prior to May 1975 and selected samples thereafter. Table 4-14 presents a statistical analysis of the salt background data for a one-year period. Similar data is available for 1975-1975. ESC concludes:

"The average ambient background sea salt concentrations presented in this analysis show three major trends:

1. There are no regular, prominent, spatial variations in the ambient background sea salt concentrations.

2. Winds from easterly directions tend to result in greater ambient background sea salt concentrations than winds from other directions.

3. Due to a number of potential causes, temporal changes have been noted in the average ambient background sea salt concentrations."

Source Term Contribution to Ground Level Source Concentration. During the period between May 19, 1975 and March 17, 1976, approximately 100 samples were exposed substantially downwind of the plant when Unit #3 was operating. For each sample the concurrent average upwind concentration was taken to be the sea salt background and subtracted from the raw data. The difference value was ascribed to the cooling tower and scrubber. Tables 4-15 A and 4-15 B give the directional distribution data for the various stations shown (most recent locations). ESC concludes,

"One comment may be made regarding the data presented in this section: The data set is too small to exhibit any statistical reliability. Of the sampling station/wind direction categories where data were available, many categories had only one value from which to obtain an average cooling tower/stack contribution. Furthermore, the average category had only two values from which to obtain an average cooling tower/stack contribution.

Due to this fact, the following statements need to be regarded as observations on the results presented above rather than conclusions regarding source contributions:

1. The cooling tower/scrubber stack sea salt contributions are frequently small enough to be within the variability of the ambient background levels or to be less than the

TABLE 4-14

Annual Means and Standard Deviations for Sea Salt Concentration when Chalk Point Unit 3 Was Not Operating, Arranged by Wind Direction and Sampling Site (3/21/74-3/20/75).

(Reproduced from Ref. 4-11)

Wind Direction	Station 1N	3N	1E	3E	3S	6W
NNE	0.34	0.34	0.41	0.47	0.36	0.28
	0.29	0.18	0.07	0.14	0.00	0.26
	3	3	3	3	1	2
NE	0.08	0.06	0.20	0.15	0.11	0.14
	0.09	0.08	0.21	0.15	0.00	0.01
	2	2	3	3	1	2
ENE	0.40	0.56	0.86	0.65	0.78	0.46
	0.79	0.90	1.24	1.12	1.14	0.63
	6	3	3	4	3	3
E	1.29	0.91	1.12	1.23	1.20	0.64
	0.81	0.75	0.84	1.02	1.10	0.74
	5	4	4	4	4	3
ESE	0.07	0.15	0.02	0.04	0.07	0.16
	0.02	0.23	0.02	0.04	0.08	0.23
	3	5	4	3	2	5
SE	0.11	0.11	----	----	----	----
	0.00	0.00	----	----	----	----
	1	1	0	0	0	0
SSE	0.32	0.30	0.27	0.39	0.39	0.40
	0.50	0.52	0.48	0.58	0.66	0.56
	7	6	6	7	6	6
S	0.31	0.25	0.17	0.15	0.09	0.26
	0.56	0.58	0.22	0.19	0.06	0.68
	14	13	14	13	8	11
SSW	0.35	0.25	0.40	0.31	0.28	0.27
	0.25	0.26	0.41	0.40	0.37	0.27
	5	6	6	6	6	5
SW	0.15	0.20	0.30	0.36	0.29	0.30
	0.17	0.21	0.28	0.30	0.16	0.31
	6	6	8	7	4	7
WSW	0.30	0.30	0.43	0.41	0.31	0.10
	0.38	0.45	0.50	0.48	0.46	0.05
	4	5	6	6	5	4
W	0.31	0.22	0.28	0.29	0.34	0.24
	0.52	0.51	0.52	0.56	0.59	0.46
	6	7	9	9	6	8
WNW	0.08	0.02	0.12	0.03	0.17	0.14
	0.11	0.00	0.10	0.04	0.21	0.17
	5	1	4	4	2	2
NW	0.06	0.07	0.07	0.07	0.04	0.08
	0.03	0.07	0.05	0.06	0.03	0.07
	8	6	4	6	3	4
NNW	0.07	0.08	0.10	0.06	0.14	0.06
	0.01	0.01	0.05	0.01	0.00	0.00
	2	2	2	2	1	1
N	0.22	0.20	0.28	0.21	0.24	0.16
	0.63	0.62	0.48	0.50	0.67	0.50
	12	12	15	14	10	13

The three values in each group, arranged vertically, are the mean, the standard deviation, and the number of values. The units for sea salt concentration are $\mu g/m^3$.

TABLE 4-15 A
(Reproduced from Ref. 4-11)

Downwind Sea Salt Concentration Less Average Upwind Sea Salt Concentration in the Vicinity of Chalk Point, Maryland.

Wind Direction	Mobile Sites	Station 1E	3E	1SE	2SE	3SE	1S	3S	6W
NNE								0.00 0.04 5	-0.01* 0.02 5
NE	MSW 0.38 0 1						0.51 0 1		
ENE	MSW 0.11 0 1						0.02 0 1	-0.05* 0 1	-0.02 0 1
E							0.21* 0 1		-0.01 0.06 2
ESE									0.40 0 1
SE									0.02* 0 1
SSE									
S									
SSW		0.15* 0.15 4	0.01* 0.11 3						-0.24 0 1
SW		0.01* 0.02 4	0.04* 0.05 3						
WSW		0.05 0.10 5	0.03 0.09 4						
W	MESE 0.02 0 1	0.02 0.04 3	0.03 0.02 3		0.00* 0.05 2			0.00* 0 1	
WNW	0.09* 0 1	0.07 0.08 8	0.00 0.01 2	0.17 0.14 6	0.02 0.04 5	0.07* 0.09 4		-0.01* 0.02 3	
NW		0.03* 0.04 2	-0.01* 0 1	-0.01 0.01 4	0.02 0.06 4	0.07 0.09 4		0.02* 0 1	
NNW		0.01* 0.02 5	0.02* 0.04 4	-0.07* 0.02 2	-0.12* 0.10 2	0.08 0 1	-0.05* 0 1	0.04 0.04 2	
N								0.02 0 1	

The three values in each group, arranged vertically, are the mean, the standard deviation, and the number of values in the category. The units for sea salt concentration are $\mu g/m^3$.

* The values were acquired in locations not substantially beneath the cooling tower/scrubber stack plumes.

TABLE 4-15 B
(Reproduced from Ref. 4-11)

Downwind Sea Salt Concentration Less Average Upwind Sea Salt Concentration in the Vicinity of Chalk Point, Maryland.

Wind Direction	Mobile Sites	1NW	2NW	3NW	3NC	1N	1NE	2NE	3NE
NNE									
NE									
ENE									
E		-0.07* 0 1		-0.16* 0 1					
ESE	MNW 0.40 0 1	1.52 0 1	0.26* 0 1	0.91* 0 1	0.15* 0 1	0.27* 0 1			0.27* 0 1
SE		-0.55 0.89 4	-1.33 1.03 2	-0.67 0 1	-0.71 0 1	0.07* 0 1	-0.68* 0 1	-1.02* 0.50 2	-1.07* 1.59 2
SSE	MNW* MNE* -0.02 -0.31 0 0 1 1	-0.03 0 1	-0.02 0 1	-0.06 0 1	-0.07 0 1	-0.36 0 1	-0.40 0 1	-0.19 0 1	-0.20 0.16 2
S	MNW* 0.04 0 1	0.03 0 1	0.00 0 1	0.00 0 1	0.06 0 1	0.03 0 1			0.00 0 1
SSW	MNE MNE* 2.93 0.30 0 0.44 1 2				0.10* 0 1	0.01 0.07 3	0.55 0.30 3	0.30 0.22 3	0.10 0.11 7
SW	MNNE* MNE 0.21 0.31 0 0 1 1	0.38* 0 1	-0.19* 0 1		0.46* 0 1	0.02* 0.03 4	0.03 0 1	0.54 0.56 2	0.12 0.18 7
WSW	MNE* -0.34 0.42 3					-0.02* 0.01 3	-0.44* 0.77 3	0.11* 0.30 3	0.05* 0.26 5
W							0.01* 0 1		
WNW							-0.21* 0 1	0.01* 0 1	-0.26* 0 1
NW									
NNW									
N									

The three values in each group, arranged vertically, are the mean, the standard deviation, and the number of values in the category. The units for sea salt concentration are $\mu g/m^3$.

* The values were acquired in locations not substantially beneath the cooling tower/scrubber stack plumes.

sensitivity of the sampling technique. This is evidenced by the negative and zero values shown in Tables 4-15 A and 4-15 B.

2. For the wind direction SSW, there were four sampling sites which were located roughly beneath the center of the resulting cooling tower/scrubber stack plumes. These sampling sites detected regularly decreasing drift sea salt contributions with increasing distance from the cooling tower and stack.

3. The sampling stations on the east side of the Patuxent River showed decreasing sea salt concentration contributions above the ambient background levels with increasing distance from the cooling tower and stack. This effect could be the result of decreasing cooling tower/stack influence or the result of the decreasing influence of brackish spray from the river as one moves away from it."

With regard to the question of the adequacy of the samples ESC concludes, "For stations operated close to the tower, the large mass median diameters seen during seasonal tests (i.e., 300-500μm) dictate the use of alternate sampling equipment. Pending examination of the results of the recent DTE test made at this site, a rotating filter paper impaction sampler may be most effective for this task."

Plume Photo Data - Photo data were analyzed for 26-time intervals in which photo, radiosonde, meteorological and drift data were available. Table 4-16 lists the identifying data for each data reduction or analysis interval. For example, for plume outline #9, it was determined from logs that exposures 18 through 28 of run 31 were required. Using these data, the average #9 plume outlines were determined and are shown as Figure 4-10. Table 4-17 gives the plume parameters for the 26 cases treated in this manner. These appear in PPSP-CPCTP-20. These data when used in conjunction with plume buoyancy data, permit calculation of the parameters (particularly the entrainment parameters) to be used in plume predictive modeling.

ESC Comments on Data Sufficiency - ESC presents a critique of data in Reference 4-11 which closes with the following summary:

"An examination of CPCTP data sufficiency and consistency for modeling results in a number of conclusions. First, the Chalk Point data set are judged sufficient as to type for model input and validation. Although not required by most models, the results of ongoing work should add individual droplet

TABLE 4-16

(Reproduced from Ref. 4-11)

Log of 35mm Slides for Production of

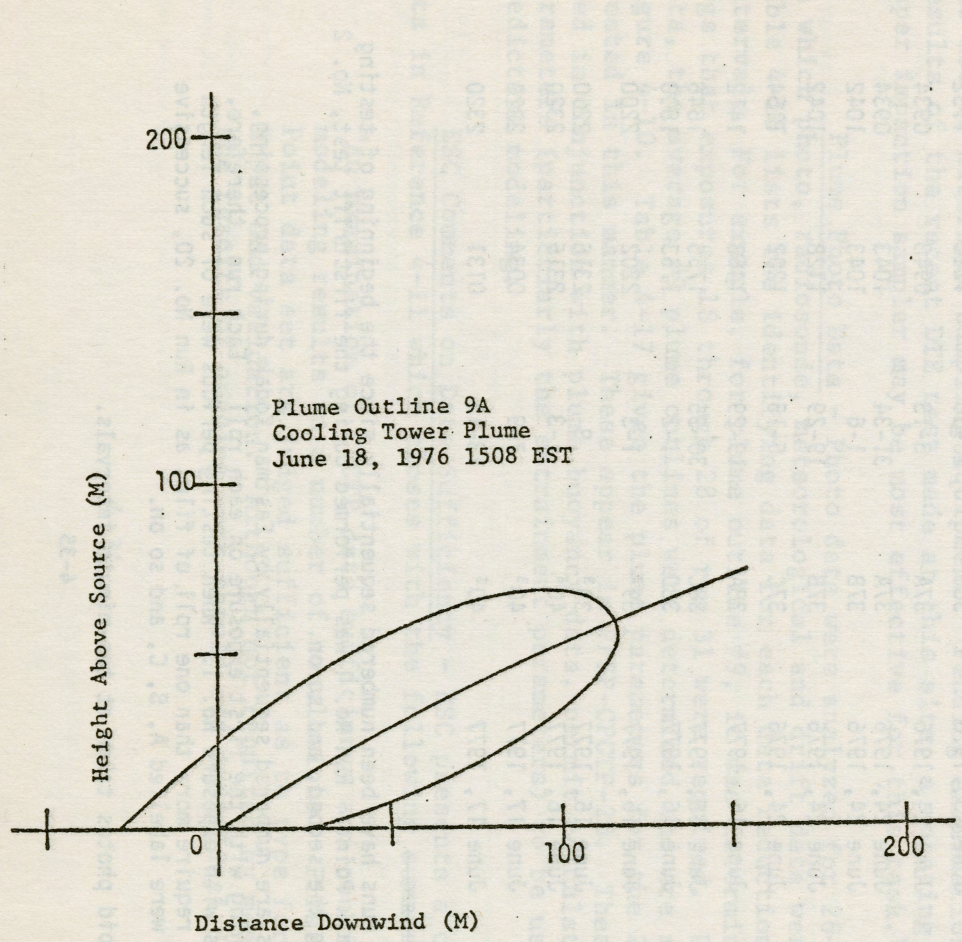
Short-Term Average Plume Outlines

Plume Outline No.	Date of Testing	Photo[1] Run No.	Exposure[2] Nos. Used	Radiosonde Release Time (EST)	Photo Run Start Time (EST)
1	Dec. 15, 1975	20A	3-12	0915	0902
2	Dec. 15, 1975	20B	35-37	1130	1012
	Dec. 15, 1975	20C	1-8	1130	1126
3	Dec. 17, 1975	24B	10-19	1600	1532
4	Dec. 18, 1975	25	5-15	1020	1002
5	Dec. 18, 1975	26A	24-32	1205	1138
6	June 17, 1976	28	1-3	1446	1454
7	June 17, 1976	28	12-22	1526	1454
8	June 18, 1976	30	7-17	1110	1048
9	June 18, 1976	31	18-28	1508	1422
10	June 18, 1976	32	4-12	1549	1536
11	June 18, 1976	32	31-35	1645	1536
12	June 19, 1976	33A	3-12	1107	1054
13	June 19, 1976	33B	2-11	1217	1206
14	June 22, 1976	35A	4-14	0930	0914
15	June 22, 1976	35A	24-34	1010	0914
16	June 23, 1976	36B	20-30	1220	1132
17	June 24, 1976	37A	3-13	0948	0934
18	June 24, 1976	37A	31-34	1043	0934
	June 24, 1976	37B	1-6	1043	1042
19	June 24, 1976	37B	19-29	1128	1042
20	June 24, 1976	37C	5-15	1202	1154
21	June 16, 1977	38A	19-29	1458	1412
22	June 16, 1977	38C	30-35	1753	1646
	June 16, 1977	38D	1-2	1753	1800
23	June 16, 1977	39[3]	1-3	2202	2200
24	June 16, 1977	39[3]	8	2316	2200
	June 16, 1977	40[3]	1-3	2316	2320
25	June 17, 1977	40[3]	7-9	0034	2320
26	June 17, 1977	40[3]	13-15	0131	2320

[1]Photo runs have been numbered sequentially since the beginning of testing at Chalk Point. Run No. 1 was performed during the first drift test, No. 2 during the second, and so on.

[2]Slides are numbered sequentially by Eastman Kodak during processing, beginning with the first exposure on each roll. Each run, therefore, begins with exposure No. 1. When testing periods were of such length as to require more than one roll of film, as in Run No. 20, successive rolls were labelled A, B, C, and so on.

[3]Polaroid photos taken at ten-minute intervals.



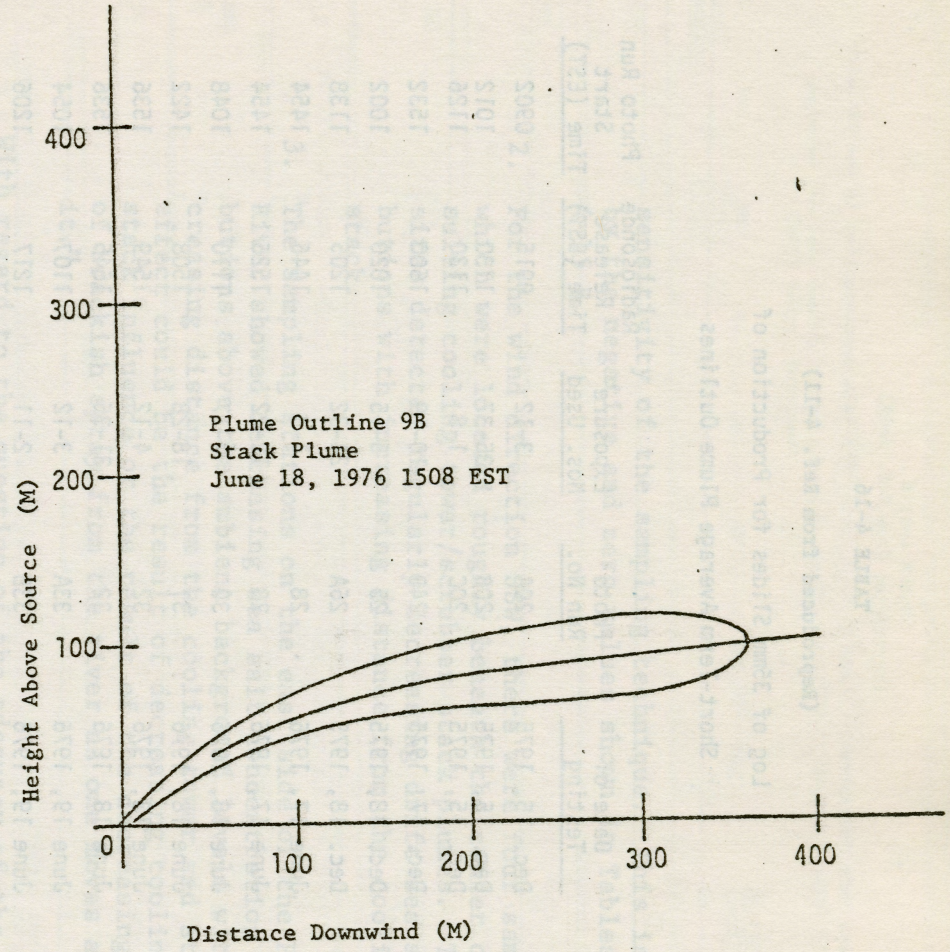


Fig. 4-10. Stack and Cooling Tower Plume Outlines

Reproduced from Ref. 11

TABLE 4-17

DIMENSIONS OF PLUMES AS MEASURED ALONG CENTERLINE

(Reproduced from Ref. 4-11)

Cooling Tower Plumes			Stack Plumes		
Drawing No.	Height (M)	Length (M)	Drawing No.	Height (m)	Length (M)
1A	48	166	1B	50	376
2A	44	99	2B	69	298
3A	108	175	3B	110	362
4A	41	171	4B	64	341
5A	86	226	5B	168	365
6A	96	188	6B	291	890
7A	112	241	7B	202	845
8A	110	221	8B	340	884
9A	58	116	9B	98	363
10A	103	134	10B	108	309
11A	76	120	11B	99	381
12A	153	194	12B	188	442
13A	101	116	13B	172	272
14A	128	248	14B	235	782
15A	129	142	15B	200	458
16A	84	73	16B	109	189
17A	102	125	17B	107	391
18A	59	74	18B	88	300
19A	57	82	19B	68	241
20A	52	63	20B	69	188
21A	108	133	21B	96	240
22A	105	126	22B	140	441
23A	106	216	23B	*	*
24A	93	234	24B	*	*
25A	110	250	25B	*	*
26A	125	257	26B	*	*

*Stack Plume end not visible in Polaroid photos.

salinity to these input variables. Ground-level measurements for model validation are judged not sufficient for two reasons, inadequate count statistics and high fluctuating sodium backgrounds. These data can be used in estimating the environmental impact of the cooling tower, however. It is recommended that in future measurements, droplet sensor sampling area be increased significantly (at least by a factor of ten). The examination of data consistency shows fluctuations in the cooling tower droplet emission data and in the downwind data as well, indicating that with the present CPCTP data base, modeling is best approached on a case-by-case basis. It is further recommended that the contribution of other droplet sources at the Chalk Point site be examined for contribution to the downwind measurements, especially the droplets originating in the fill area."

An Editorial Comment

In editing the analysis conducted by another contractor, we have attempted not to slant the results through improper selections. Nevertheless, it is strongly urged that users who intend to quote these results or use them in other studies refer to Reference 4-11 for the full discussion of this material as given by ESC.

RESULTS OF MRI ANALYSIS

MRI's primary role in the Chalk Point Cooling Tower Program was in the area of data acquisition using its instrumented aircraft, and in the reduction of that data into forms suitable for later analysis. The MRI program and samples of the data obtained have been summarized in Chapter III. In addition, however, MRI made some measurements of chemical interaction between the cooling tower and stack plumes. The results of these tests are directly interpretable and indicate the interaction to be very small. A summary of MRI's results are given in Reference 4-37.

Sulfur Dioxide Concentration. Sulfur dioxide concentrations were measured with a Theta chemical cell sensor. Half second averaged adds a significant amount of water to the boiler plume in the form of both droplets and vapor. Temperatures and concentrations of water and boiler plume constituents are much higher within the plume prior to dispersion. Reaction rates are, therefore, likely to be much higher in the exhaust system than at any time after emission from the stack. It, therefore, appears that reactions involving SO_2 and water occur within the boiler plume prior to mixing with the cooling tower plume. Since the boiler plume already contains sufficient water for the chemical reactions to occur, the addition of more water from the cooling tower plume during plume mixing is likely to have only a small effect. There

is insufficient experimental evidence to indicate any chemical reactions within the interaction zone of the boiler and cooling tower plumes.

Sulfuric Acid Mist Concentration. Sulfuric acid concentrations were measured by two methods: the Chemical Film Sampler for droplets larger than approximately 30μm. In both cases the droplet collection surface was treated with quinine. The quinine sulfate is more stable than sulfuric acid so the sample can be stored. It is also fluorescent so that its presence can be detected by illumination with ultraviolet light.

Preliminary laboratory tests have shown that the quinine fluorescence method is sufficient to detect less than 1 μℓ of 0.02 N sulfuric acid (equivalent to approximately 1 μg of H_2SO_4). A single pass through a plume 100 meters wide typically provides a sample volume of approximately 1/4 m^3. The overall sensitivity under these conditions is, therefore approximately 4 $\mu g/m^3$. The cascade impactor limit of sensitivity is approximately 150 $\mu g/m^3$ because of its lower sampling rate (approximately 2 liter/sec.).

The highest concentrations of sulfuric acid were detected in the boiler plume before mixing with the cooling tower plume (using the impactor sampler). The quantity, however, was near the threshold sensitivity of the analytical method (on the order of 150 $\mu g/m^3$). Because of plume diffusion and low reaction rates in the interaction zone, concentrations were lower in the interaction zone measurements.

Vapor Plume and Drift Data. Complete tabulations and plots of plume and drift data appear in References 4-37 and 4-38. These data can be of considerable value in studies of vapor plume dynamics and thermodynamics. In addition, it may be possible to use a small amount of the chemical film sampler data in large aerosol trajectory studies. Very little use has been made of this data to date because the emphasis of the analysis has been directed to drift studies and the drift data available in the data is small. The reader is urged to consult References 4-37 and 4-38 for a complete exposure to this data.

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APPENDIX A

INSTRUMENTATION SYSTEMS

While various elements of the Chalk Point Cooling Tower Program require different data, some commonality of requirements existed and is implicit in the instrumentation list. Table A-1 presents a tabulation of the instrumentation used in the acquisition of data to meet the various program objectives.

Descriptive literature relative to these equipment items is extensive. Reference A-1, pages 99-126 and 427-482 provides the most readily accessible source of such descriptive information. More detailed information describing the equipment provided by the various contractors is provided in their project reports, References A-2 through A-9.

TABLE A-1 INSTRUMENTATION

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
COOLING TOWER INTERNAL DYNAMICS						
Circulating water system	Inlet conditions (Condenser to tower)	Inlet water temp.	PEPCO/ESC	Rosemount Platinum RTD 1	0.2°C	10 min.
		Water flow rate	PEPCO/ESC	Ellison No. 2203 Pilot Tube 2	Unknown	10 min.
			PEPCO	Ellison Annubar F. O. Fan Room 3		1 hour
	Outlet conditions (tower to condenser)	Outlet water temp.	PEPCO/ESC	Rosemount Platinum RTD 4	0.2°C	10 min.
		Blow down rate	PEPCO/ESC	Darshall Flume 5	Resolution = 12,500 gal.	10 min.
	Basin conditions	Make-up water temp.	PEPCO/ESC	Rosemount Platinum RTD 6	0.2°C	10 min.
		Make-up Flow rate	PEPCO/ESC	Ellison Annubar 7	± 1.2 - 2.4% of actual flow	10 min.
		Mineral concentration	ESC	Crab sample and Chemical Analysis 8	± 0.05%	N/A
	Heat Load	Generating Load	PEPCO	Three Phase Watt Hour Meter and Computer 9	0.1% or less of reading	hourly (Load Weighted)
Cooling tower Emmissions	Fluid Dynamic Properties	Vertical flow velocity	ESC	Gill Propeller Anemometer 10	0.5 mph Lower Threshold	10 min.
	Thermodynamic Properties	Dry bulb temp.	ESC	Thermistor 11	± 0.15°C	10 min.
		Wet bulb temp.	ESC	Thermistor 12	+ 0.15°C	10 min.
	Physical Properties	Drift drop size distribution	ESC	PILLS II-A 13	± 15%	variable
				Sensitive Paper 14	± 15%	variable
		Liquid drift Water content	ESC	Calculated from PILL-II and sensitive paper drop size distrib. 15	N/A	variable
		Total Liquid Water content	This parameter is not being measured			
		Average Na and Mg Mass Flux	ESC	Isokinetic sampler 16	± 15%	1 - 4 hours
		Mineral Mass Content	ESC	Isokinetic sampler 17	± 15%	1 - 4 hours
		Instrument package location	ESC	Measurement by Plum Line 18	± 2 %	N/A

TABLE A-1 INSTRUMENTATION (CONTINUED)

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
COOLING TOWER PLUME						
Aircraft Positioning	Location	Position over land ref.	MRI	Visible land marks Event Marker Manual 19	± 300 ft.	N/A
	Altitude	Pressure	MRI	Computed from pressure transducer with temp. corr (0-15 psi) 20	± 20 ft.	0.5 sec.
	Velocity	True air speed	MRI	A/C Pitot-static and airspeed corrected for temp & pres 21	± 5 mpt	0.5 sec.
	Time	Local time	MRI	Digital clock (elapsed time, sec.) 22	0.5 sec	0.5 sec.
Moist Plume (Air/Vapor)	Thermodynamic/ meteorological properties (as function of downwind distance) Used to define moist plume geometry	Temperature profiles	MRI	Fast ISI (Hot wire sensor)	± 2°C	0.5 sec.
				Slow YSI Temp. sensor 23	± 1°C	0.5 sec.
		Water vapor content	MRI	EC&G Dew Point Sensor 24	± 1°C	0.5 sec.
		Turbulence	MRI	MRI UTIS 25	± 1R	0.5 sec.
Visible Plume (Fog)	Geometry (Aircraft traverses)	Visible plume geometry and visibility	MRI	Nephelometer 26	± 10%	0.5 sec
		Visible plume rise & length	ESC	35 mm Camera 27	~3%	N/A
	Thermodynamic properties (as function of downwind distance)	Total liquid water content	MRI	PMS probes (ASP and CPS) (Integrated) 28	± 100%	0.5 sec.
	Physical Properties (as a function of downwind distance)	Droplet Size Distribution	MRI	PMS Probes 29	± 20%	0.5 sec.
				Cascade Impactor 30	± 20%	variable
Salt Drift Droplet Plume	Geometry and Trajectory (Aircraft Traverses)	Drop Concentration as F (x) in Plume	MRI	PMS probes 31	± 100%	0.5 sec.
	Plume Physical and Chemical Properties (Function Down Wind Dist.)	Drift Drop Size Distribution	MRI	PMS probes 32	± 20%	0.5 sec.
		Total Drift Liquid Content	MRI	PMS probes 33	± 100%	0.5 sec.
		Sodium Chloride (NaCl & H_2SO_4)	MRI	MRI Sensitive Film >30 μm MRI Cascade Impactors >30 μm 34	Unknown	variable

TABLE A-1 INSTRUMENTATION (CONTINUED)

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
COOLING TOWER PLUME (Cont'd)						
Ground Level Salt Measurements	Ground Level Ambient Salt. Conc. (Na)	Salt Conc.	ESC	Airborne Particle Sampler (Rotating Impaction) 35	see footnote 5	~5 hours
	Drift Droplet Conc. and Size Distrib.	Droplet Conc. & Size Dist.	ESC	Sensitive Paper Strip 36	± 15%	~2 hours[4]
	Mineral Conc. & Size Dist. of Mineral Carrying Droplets	Droplet Conc. & Size Dist.	ESC	Cascade Impactor 37	± 15%	4-5 hours
	Drift Mineral Deposition Flux	Drift Mineral Deposition Flux	ESC	Deposition Cylinder (Funnel and Bottle Assembly 38	± 15%	~6 hours[4]
	Surface Drift Deposition (prop.)	Surface Drift Drop Size Dist.	ESC	Sensitive Paper Drift Sampler 39	± 15%	~5 hours[4]
	Salt Deposition Rate	Salt Weight per Unit Area	U of Md Agronomy	Dust Fall Collectors 40	±0.05 ppm Na^+ or Cl^- in deionized water	monthly
	Salt Deposition Rate[1]	Mass of Salt per Unit Time & Area		41		
	Salt Concentration in soils	Conc. of salt ions in soils	U of Md Agronomy	Soil Samples & chemical analysis 42	±2ppm (extract. & atomic Absorp. unit.	yearly
	Salt Deposition on Agronomic Plants	Foliar Total Salt Load	U of Md Agronomy	Plant Samples, Visual Inspection & Std. Chemical Tech. 43	± 5ppm (Extract. & Atomic Absorp. unit.	N/A
	Salt Deposition on Woody Species	Foliar Salt Na^+ and Cl^-	U of Md Agronomy	Woodland Sampling Test Plots & Std. Chem. Analysis 44	Na ± 7µg/g (per NBS SRM 1571 Orchard Leaves) Cl + 1.0 µg/g	seasonal
	Crop Yield and Quality (Aeronomy)	Weight per Unit Area & Grade	U of Md Agronomy	Est. Cultural, Harvesting Processing Procedures & Grdng.45	± 50 kg/ha	seasonal
	Woody Plant Symptoms (Botany)	Eval. of Foliar Health Correlated with Salt Dep.	U of Md Botany	Visual Exam. & Indexing to determine injury to leaves 46	N/A, Semi quantitive	seasonal
	Effects of Salt in Soil	Soil Microbial Pop. & soil mineral content of NaCl Treated soil	U of Md Agronomy	Std. Chem. testing of soil samples 47	± 2ppm for salen ± 10% of population for microbes	yearly
	Symptoms of Background Air Pollution Damage	Ozone, Ambient Air & Filtered Air Comparison for Select. Species	U of Md Botany	Two On-site Open-top Field Chambers 48	N/A, Semi-quantitive	seasonal
	Est. Effects of Saline Aerosols on Foliage	Cl^- Content of Dried Leaves & Estimate of Foliar Injury	U of Md Botany	Field Plot Testing of various Conc. of Saline Aerosol Sprays on Plants 49	Cl^- ± 1.0 µg/g	seasonal
	To Est. a Threshold of Salt Damage on Plants	Metabolic Index & Visual Symptoms	U of Md Agronomy	Field & Lab. treatments of various concen. of saline Aerosol Sprays 50	± 5 ppm (Extract, & Atomic Absorp. unit.)	seasonal weekly

TABLE A-1 INSTRUMENTATION (CONTINUED)

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
GASEOUS EFFLUENT PLUMES						
Ground Level Concentrations (Units 1,2,&3)	SO_2 Deposition Rate	Weight per unit area	U of Md	Huey Sulfation Plates 51	± 0.02 mg SO_3/100 cm	N/A
	Geographic Dist. of Ground Level Sulfur concentration	Total Sulfur	EMI	Van Traverses with total Sulfur Monitor 52	± 1% repeatable	None
	Sodium, Chloride and Sulfuric Acid Mist Deposition Rates[2]	Weight per Unit Area Sodium Chloride H_2SO_4 Mist		53		
Stack Emissions Units 1 and 2[3]	Chemical Composition	SO_2 and Particulate rates	PEPCO	Estimation from Coal Analysis & Boiler Operations 54		
	Thermodynamic and Physical Properties	Temperature	PEPCO	Thermocouple or RTD 55		
		Flow Velocity	PEPCO	Design Specif. 56		
		Flow Volume	PEPCO	Design Specif. 57		
Stack Emissions Unit No. 3	Thermodynamic and Physical Properties 400 ft. stack level	Temperature	ESC	Thermocouple 58	± 3° F	1 min.
		Flow Velocity	ESC	Pitot Tube 59	± 5%	30 sec.
		Flow Volume	ESC	Computed from Flow Velocity & Stack Dimensions 60		
		Drift Droplet Size Distrib.	ESC	Sensitive Paper 61	R-14	variable
		Drift Water Content	ESC	Computed from Drop Size Distrib. 62	N/A	variable
		Total Liq. Water Cont. this parameter is not being measured.				
	Chemical Composition 400 ft. stack level	Sodium and Magnesium Mass Flux	ESC	Isokinetic Sampler 63	R-17	1-2 hr per Traverse
Stack Emissions Unit No. 3	Chemical Composition	Chloride Mass Flux 1	ESC	Isokinetic Sampler 64	R-17	1-2 hr per Traverse
		SO_2 and Particulates	Optional	Standard EPA Stack Analysis 65	. . . . .	
		Sulfuric Acid Mist	Not contracted	66	. . . . .	
Unit No. 3 Stack Plume (Air/Vapor)[3]	Thermodynamic and Physical Properties	Temperature	Not contracted	Aircraft Fast TSI Sensor 67	Sampling & Instrument Characteristics Similar to	
		Water Vapor	Not contracted	Aircraft BG&G Dew Point 68	Sampling & Instrument Characteristics Similar to	
		Liquid Water Content	Not contracted	Aircraft Computed from PMS Probes (ASSP and OAP) 69	Sampling & Instrument Characteristics Similar to	
		Plume Drop Size Distribution	Not contracted	Aircraft PMS Probes (ASSP And OAP) 70	Sampling & Instrument Characteristics Similar to	
		Plume Dimensions Length & Width	Not contracted	Aircraft Traverses of Temp, Dew Pt & SO_2 71	Sampling and Instrument Characteristics Similar to	
		Plume Rise	ESC	35mm Camera 72	R-27	variable
			Not contracted	Aircraft Mid Plume Traverse after Plume Bend Over 73	Sampling & Instrument Characteristics Similar to	

TABLE A-1 INSTRUMENTATION (CONTINUED)

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
GASEOUS EFFLUENT PLUMES (cont'd)						
	Geometry and Trajectory	Horizontal Dist. of SO_2 in Plume 4	EMI	Van Traverses with Correlation Spectrometer (COSPEC) 74	± 15PPM-M	None
		Vertical Plume Dist.[4]	EMI	Correlation Spectrometer Vertical Transections from Pan Head 75	± 15PPM-M	None
	Chemical Composition	SO_2 Concentration	Not contracted	Aircraft SO_2 Theta Sensor 76	Sampling and Instrument Characteristics Similar to	
		Sulfuric Acid Mist	Not contracted	Aircraft Chemical Sensitive Film Cascade Impactor 77	Sampling and Instrument Characteristics Similar to	
		Particulate Size and Composition Inc. Sodium & Chlorides	Not contracted	Aircraft Chemical Sensitive Film Cascade Impactor 78	Sampline and Instrument Characteristics Similar to	
Interaction Zone, Cooling Tower and Stack Plumes	Thermodynamic and Physical Properties	Temperature	MRI	Fast TSI Sensor 79	± 2° C	0.5 sec.
		Water Vapor	MRI	EG&G Dew Pt Sensor80	± 1° C	0.5 sec.
		Liquid Water Content	MRI	Computed from PMS Probes (ASSP & OAP)81	± 100%	0.5 sec.
		Plume Drop Size Distribution	MRI	PMS Probes (ASSP and OAP) 82	± 20%	0.5 sec.
	Geometry, Spatial Extent	Length, Width and Depth	MRI	Aircraft Traverses of Temp, Dew Pt & SO_2 83	± 300 ft.	various
	Chemical Composition	SO_2 Concentration	MRI	SO_2 Theta Sensor 84	± 5 %	0.5 sec.
		Sulfuric Acid Mist	MRI	Chemical Sensitive Film Cascade Impactor 85	Unknown	Cross Section
		Particulate Size & Composition Inc. Sodium Chlorides	MRI	Chemical Sensitive Film Cascade Impactor 86	Unknown	Cross Section
	Visibility	Visibility	MRI	Nephalometer 87	± 10%	Continuous
METEOROLOGY						
Ambient Atmosphere	Low Level Meteorology (100-meter Tower)	Wind Direction 7,50 & 100 Meter levels	ESC	3 Axis Gill Type Anemometer 100 Meter Level Bendix Vane 7 and 50m Levels 88	± 3-5 Degrees	30 min.
		Wind Speed 7,50 & 100 Meter Levels	ESC	3 Axis Gill Type Anemometer 100 Meter Level Bendix Vane and 50m Levels 89	± 0.5 to 1m/sec	30 min.
		Temperature (100m Level)	ESC	Platinum Wire RTD 90	± 0.5°F or better	30 min.
		Temp. Difference (Lapse Rate) 50-100 Meter 7-100 Meter)	ESC	Platinum Wire RTD 91	± 0.5°F or better	30 min.
		Dew Point Temp. 100m Level	ESC	EG&G Dew Point Sensor 92	± 0.5°F	30 min.
		Dew Point Temp. 7m Level	ESC	Yellow Springs Dew Pt. Sensor (LICI) 93	± 0.8% or ± 0.4°C	30 min.

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TABLE A-1 INSTRUMENTATION (CONTINUED)

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
METEOROLOGY (cont'd)						
Ambient Atmosphere (cont)	Surface Meteorological Observations [4]	Precipitation	U of Md Agronomy	Rain Guage 94	0.01 in.	monthly
		Temperature	ESC/APL	Hygrothermograph 95	± 1°C	
		Relative Humidity	ESC/APL	Hygrothermograph 96	± 5%	
		Barometric Pressure	ESC/APL	Microbarograph 97	± 0.5mb	
		Visibility	ESC/APL	Observation (Std USWB Observing Method 98	~± 0.2	
		Cloud Cover and Ceiling Height	ESC/APL	Observation (Std USWB Observing Method 99	~± 2000 ft.	
Upper Air Ambient Atmosphere	Thermodynamic and Hydrodynamic Properties as a Function of Altitude	Temperature	APL	Radiosonde Thermistor 100	Manual System ± 0.5°C Automatic Sys. ± 0.1°C	
		Relative Humidity	APL	Radiosonde Hygristor 101	Manual System ± 5% Auto. System ± 2%	
		Pressure	APL	Radiosonde Aneroid cell 102	Manual System ± 1 mb Auto. System ± 1 mb	
		Wind Direction	APL	Rawinsonde or Double Theodolite Pibal 103	Manual System ± 3 Deg. Auto. System ± 2 Deg.	
		Wind Speed	APL	Rawinsonde or Double Theodolite Pibal 104	Manual System ± 1 m/sec. Auto. System ± 0.5-1 m/sec.	
		Virtual Temp.	APL	Computed from radiosonde temp. and relative humidity 105	...same as 100 and 101 ...	
		Potential Temp.	APL	Computed from radiosonde temp. 106	...same as 100 ...	
		Dew Point	APL	Computed from radiosonde rel. hum. 107	...same as 101 ...	
		Dew Point Difference	APL	Computed from radiosonde rel. hum. 108	...same as 100 and 101 ...	
		Mixing Ratio	APL	Computed from radiosonde rel. hum. 109	...same as 101...	
		Vapor Pressure	APL	Computed from radiosonde rel. hum. 110	...same as 101...	
		Dry Air Density	APL	Computed from radiosonde pres & temp 111	...same as 100 and 102...	
		Moist Air Density	APL	Comp. from radiosonde temp & rel. hum. 112	...same as 100, 101 & 102 ...	
UNIT NO. 3 OPERATING CONDITIONS						
Stack No. 3 Scrubber System (Water)	Inlet Conditions	Make-up Flow Rate	PEPCO	113		
	Outlet Conditions	Blowdown Flow Rate	PEPCO	114		
	Basin Conditions	Salinity (Na conc.)	ESC	Crab Sample Chem. Analysis 115	± 0.5%	N/A

TABLE A-1 INSTRUMENTATION (CONTINUED)

Element to be Characterized	Properties to be Determined	Parameters Measured	Responsible Agency	Instrumentation and Reference No.	Measurement Accuracy	Averaging Time
FLUORESCENT DYE DEPOSITION DATA						
Total Deposition	Total Dye Deposition	Mg. of Sodium	JHU/APL	10.5" funnel bottle collectors (with stand)	≈10%	≈4 hr
	Total Salt Deposition	Ng. of Rhodium wt dye	JHU/APL	10.5" funnel bottle collectors (with stand)	≈15%	≈4 hr
Droplet Deposition	Size Distribution Dyed Drops	Number of droplets per size interval	JHU/APL	10.5" millipore HA filter papers treated for chloride detection (with stand)	$\approx \sqrt{N_{ct.}}$	≈4 hr
	Size Distribution Saline Drops	Number of droplets per size interval	JHU/APL	10.5" millipore HA filter papers treated for chloride detection (with stand)	$\approx \sqrt{N_{ct.}}$	≈4 hr
	Size Distribution of all Aerosols	Number of droplets per size interval	JHU/APL	10.5" millipore HA filter papers treated for chloride detection (with stand)	$\approx \sqrt{N_{ct.}}$	≈4 hr

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